MACROECONOMICS AND THE ENVIRONMENT: REVISIONS TO SELECTED FRAMEWORKS AND POLICY ANALYSIS

TAN SECK LENG

(MCom, University of New South Wales)

(BCom, University of Sydney)

A THESIS SUBMITTED FOR THE DEGREE OF:

DOCTOR OF PHILOSOPHY IN PUBLIC POLICY

LEE KUAN YEW SCHOOL OF PUBLIC POLICY

NATIONAL UNIVERSITY OF SINGAPORE

2012

Acknowledgements

I am grateful to Professor Dodo Jesuthason Thampapillai for his guidance, leadership, supervision, and patience towards the development of this thesis.

I am also thankful for valuable suggestions from Professor Wu Xun, Professor Bhanoji Rao, and Professor Charles Adams. Thanks are also due to Professor Darryl Jarvis, Professor Gopi Rethinaraj, Professor Michael Howlett, Professor Hui Weng Tat and Professor Kenneth Paul Tan.

I would also like to thank my PhD colleagues at the Lee Kuan Yew School of Public Policy (LKY School), especially Allen Lai and Leong Ching.

Lastly, I would like to thank the LKY School for offering me a place to interact and exchange ideas with academic gurus.

This has truly been a humbling experience and it has made me realise that the sweetest victories are usually personal in nature.

Table of Contents

Executive Summary

Macroeconomic policies aim to stabilise an economy in the short term and to maintain a steady rate of economic growth and employment in the long term. The three primary policy variables are: level of aggregate output, employment and inflation. However, steps should be taken to ensure that the natural environment is considered. Traditional methods of macroeconomic policy formulation consider the state of an economy but exclude the state of environmental capital (KN). Therefore, the challenge addressed in this thesis is the provision in macroeconomics for affording recognition to KN besides the traditional factors of labour (L) and capital (KM). Such recognition would enable the formulation of effective and meaningful policies.

This thesis argues why and how current practices of policy formulation must change by recourse to the utilisation of environmental-macroeconomic (EM) frameworks. First, a methodological framework for measuring KN is proposed. This step is followed by the internalisation of KN into traditional macroeconomic frameworks to demonstrate how an economy's capacity, in terms of the steady state equilibrium (SSE), would be affected. It is shown that the SSE is reached earlier in the EM framework when the allowance for the depreciation of KN has been made. This result suggests that the capacity of an economy may be overstated if KN is not considered. Furthermore, when the SSE is formalised with respect to its relationship with the primary macroeconomic policy variables, the results show that the EM framework leads to significantly different policy choices compared to the standard macroeconomic framework.

This thesis is structured as follows. The first chapter provides an introduction to this study and a synoptic description of the standard macroeconomic framework and relative implementation of policy practices. The next chapter addresses the challenges of the standard frameworks; these challenges are demonstrated in the literature on environmental accounting and environmental-macroeconomics (EM). This literature is classified on the basis of materials that (a) focus on concepts and paradigms and (b) extend the conceptual / dogmatic premises to empirical applications. Chapter Three addresses questions that arise in the context of recognising environmental capital (KN) in the standard macroeconomic framework. These questions help to pave the way for proposing an alternative EM framework for policy analysis. Chapter Four addresses the measurement of KN and its utilization with reference to selected Organisation for Economic Co-operation and Development (OECD) economies, namely Australia, Canada, France, Germany, Japan, Korea, Mexico, New Zealand, Norway, United Kingdom and the USA. Chapter Five provides a comparison of the economies' steady state equilibrium between the standard macroeconomic framework and the EM framework. Chapter Six presents the methodology for analysing how macroeconomic goals are affected by the steady state equilibrium. This is followed by a discussion of significant findings of policy ranges when the EM model is used as opposed to the standard macroeconomic model in Chapter Seven. Finally, this thesis concludes with a summary of the research and presents the directions for future research.

In the animated film "Happy Feet", penguins experience food shortages. The ecosystem is upset due to the ocean being overused as a sink from accumulated waste pollution. The penguins speculate (but never actually find out) the reasons why fish are scarce. It takes a gullible young penguin to uncover the truth from his stubborn elders. Perhaps, it is an easier pill to swallow when humans watch it happen to the penguins, and when it is not yet happening to humans. The truth was illustrated by Smith and Lourie (2009) in “Slow Death by Rubber Duck”, where the human body was used as an analogy to the environmental sink. The toxins that humans consume from their daily routines remain in the body and pose long-term health risks.

Most of us *know* and are more than *aware* that the environment is “sick”. Samuelson and Nordhaus (2001) suggested that assets such as land, natural resources such as oil and coal, and environment assets such as clean air, national reserves and white sandy beaches should be accounted for. This may help account for the extent of the “sickness”, but this will not convince policy makers of the value in practicing such accounting. What will be of interest is how this will impact the macroeconomic indicators of national income, employment and inflation for an economy with respect to the SSE. However, quantifying the *know* and the *aware* may be difficult to accept for some.

List of Tables

List of Figures

List of Acronyms

AD	Aggregate Demand
AP	Air Pollution
AS	Aggregate Supply
C	Consumption
CE	Compensation to Employees
CH_4	Methane
CO_2	Carbon Dioxide
CV	Contingent Valuation
C-D	Cobb-Douglas
EM	Environmental-Macroeconomics
G	Government Expenditure
GCF	Gross Capital Formation
GDP	Gross Domestic Product
GFC	Global Financial Crisis
GHG	Greenhouse Gas
H-D	Harrod-Domar
HP	Hodrick-Prescott
HFC	Hydrofluorocarbons

I	Investment
IANA	Income Approach to National Accounts
KM	Capital
KN	Environmental Capital
L	Labour
NX	Net Exports
N_2O	Nitrous oxide
NIA	National Income Accounting
NNP	Net National Product
NRA	Natural Resource Accounting
OA	Organic Agriculture
OS	Operating Surplus
OECD	Organisation for Economic Co-operation and Development
PFC	Perfluorinated Compounds
RF	Reforestation
REDD	Reducing Emissions from Deforestation and Degradation
S	Savings
SD	Soil Degradation
SF_6	Sulphur Hexafluoride
SNA	United Nation's System of National Accounts
SSE	Steady State Equilibrium
SEEA	System of Integrated Environmental and Economic Accounting
TFP	Total Factor Productivity or the Solow residual
WDI	World Development Indicators
WTP	Willingness to pay
Y	Income

Chapter One – Introduction and the Standard Macroeconomic Framework

1. AIMS OF THE STUDY

Aims of the Study

The main aim of macroeconomic policy is stabilisation. That is, to close or reduce gaps relating to output, employment and inflation both in the short run and the long run. The main issue raised in this study is that the standard macroeconomic framework currently in use does not adequately represent these gaps. The contention is that these gaps are better represented by the adoption of an environmental-macroeconomic (EM) framework. The superiority of the EM framework rests on the inclusion of environmental capital (KN) as an integral component of the economy. As a result, the use of the EM framework facilitates the choice of policies that safeguard KN and uphold the principles of sustainability. Selected policy interventions must fulfil the requirement of minimal damage to the environment whilst economic growth is maintained. Therefore, the main objective of this study is to demonstrate both "why" and "how" current practices of policy formulation must change by recourse to the utilisation of EM frameworks. The main outcome of this study is the demonstration of methods for deriving a distinct set of stabilisation policies that addresses not only output, employment, and inflation but also sustainability with respect to steady state equilibrium. The policy implication in relation to this study is to close the gaps relating to output, employment and inflation. Hence, the key determinant for formulating stabilisation policies is the difference in the magnitude of the gaps when the EM framework is used as opposed to the standard macroeconomic framework.

A brief review of standard concepts in macroeconomics is considered next. This review facilitates the illustration of "why" and "how" environmental and natural resource variables can influence macroeconomic processes.

2. STANDARD MACROECONOMIC FRAMEWORK

The economic model of aggregate demand and aggregate supply (AD-AS) is used to analyze economic fluctuations for most economies. Aggregate demand (AD) is the quantity of goods and services that households, firms and the government would want to buy at each price level. Aggregate supply (AS) is the quantity of goods and services that firms would choose to produce and sell at each price level. AD and AS are combined to determine the equilibrium level of output and price for the economy. An economy can fluctuate, for example it can grow, contract, or stay the same. Its performance is measured by the growth rate of output produced in a given time period. In addition, policy makers would also be interested in the levels of unemployment and inflation for the same time period to avoid any macroeconomic in-balances. Thus, the level of output, unemployment and inflation are key indicators that determine the health of an economy. Based on the AD-AS model, there are three basic macroeconomic policy areas of intervention: the level of aggregate output, unemployment and inflation.

Unemployment

Economists' definition of full employment could include existence of unemployment in terms of frictional and structural categories. This level of unemployment is an economy's natural rate of unemployment. There are other types of unemployment, namely frictional, structural and cyclical. Frictional unemployment occurs because the labour market is always in a state of flux and is dependent on the structure of the labour market (Dornbusch, Fischer, and Startz, 2008). Frictional unemployment refers to people who are between jobs or looking for jobs for the first time. Such a scenario is also termed voluntary unemployment. This unemployment is dependent on labour turnover and the time taken to match the appropriate worker to an appropriate job. Selected economies may provide unemployment benefits to people who have been laid off. These unemployment benefits may increase frictional unemployment, as the unemployed can choose to remain unemployed or take their time to look for the ideal job. Deterioration in frictional unemployment may be unintentional. But such benefits can help improve the ability of economies to match workers to the most appropriate job (Mankiw, 2004), and a certain level of frictional unemployment is essential to the smooth running of a rapidly changing dynamic economy (Frank and Bernanke, 2009). Structural unemployment occurs when the unemployed do not have the skills necessary to take advantage of employment opportunities. In this scenario, there is a mismatch between the needs of the workers and the requirements of the job vacancies. Unemployment of a structural nature is affected by job location and worker's skill sets. Job vacancies may exist but they are in a region different from that of the unemployed, and workers may be under- or over-qualified for available jobs, resulting in a mismatch. Alternatively, discrimination can also prevent a worker from getting a job, even when the worker is qualified because employers may practice discrimination against a select group of people. An employer may advertise a position to fulfil the hiring process even though an internal candidate is certain to fill the position. An external advertisement might, however, fulfil the legal requirement to search internally and externally for the best candidate. Structural unemployment can also be a result of impediments to employment, such as minimum wages and / or unions' demands to keep wages above equilibrium. Higher wages affect the structure of the labour market and contribute to unemployment. As an economy fluctuates between expansion, stagnation, and contraction, there will be similar fluctuations in unemployment around the natural rate of unemployment. This type of unemployment is termed cyclical unemployment. Cyclical unemployment is the difference between the actual rate of unemployment and the natural rate of unemployment. This occurs when demand for labour is low and can also be termed as involuntary unemployment. Zero cyclical unemployment can occur when an economy experiences minimal economic fluctuations. However, an economy will always experience positive frictional and structural unemployment even when there is equilibrium in the labour market. Therefore, an economy will realistically never obtain zero unemployment as there will always be people between jobs, new entrants to the workforce, and a mismatch of workers' skill sets with job requirements. This is particularly evident with globalisation, ease of immigration, and improved technology; technological advancement can translate into a lower dependence on labour and a higher level of productivity.

Inflation

Inflation is defined as the overall increase in prices and is primarily a result of an increase in the quantity of money. Historically, the relationship between money and prices is theorised by the quantity equation. The quantity equation of money states that the money stock multiplied by the velocity of money equals the price level multiplied by income. If the velocity of money and income are assumed to be fixed, any changes in the money supply will also change the price level. As the measurement of the variables is usually in percentage terms, it can be concluded that the rate of growth of the money supply equals the rate of inflation. When prices rise, the value of money falls; and when prices fall, the value of money rises. Hence, the value of money is measured by the price level, and the price level is determined by the demand for and supply of money.

Demand for money can be broadly classified as transactive, precautionary, or speculative. Firstly, money is demanded for purposes of making transactions as it is a medium of exchange for goods and services. A higher price level will increase the demand for money as it is now of a lower value, that is, a greater amount of money is required to purchase the same amount of goods and services. Secondly, money is demanded as a precautionary measure to meet unexpected circumstances. Money is held as cash to make unanticipated payments. However, the holding of credit cards is likely to reduce the demand for precautionary money. Lastly, money is demanded for speculative purposes, according to the expected returns and risks involved. When there is an increase in expected returns on interest-bearing assets, there is less money demanded. In this case, money would be much better off invested in interest-bearing assets. A high interest rate increases the cost of holding money. Thus, the interest rate is the opportunity cost of holding money. The supply of money can be controlled by the central bank through open-market operations and reserve requirements (Mankiw, 2004). Open-market operations refer to activities in which the central bank issues bonds or purchases bonds from the public. The objective is to manipulate an economy's money supply. When the central bank issues bonds, the money supply falls as the public's money is used to purchase these bonds. However, when the central bank purchases bonds, the money supply rises as money flows to the market from the purchase of the bonds. Reserve requirements are regulations set by the central bank on the minimum amount of reserves that financial institutions must hold against deposits. The money supply falls when the reserve ratio is higher and rises when the reserve ratio is lower. The central bank can use these tools to influence the money supply. Success in influencing the money supply is dependent on the credibility and performance of the economy. When households have confidence in the financial institutions, they will deposit more money. When an economy is growing, financial institutions will be more willing to lend as capital is easily obtained. The opposite is true when households have less confidence and when an economy is contracting. At equilibrium, the overall level of prices would be at a level at which money demand equals money supply. The overall price level of an economy is also termed inflation.

Inflation can be classified into two categories, namely demand-pull and cost-push[1]. Demand-pull inflation occurs when prices are "pulled-up" by excess demand for goods and services. There is too much money chasing too few goods. Cost-push inflation occurs in the absence of any excess demand for goods and services and is caused purely by supply side disturbances. Prices are pushed upwards by increasing costs of production, such as increased wages, producer mark-ups and increased in interest rates. In the short run analysis of the AD-AS framework, increasing aggregate expenditure at low levels of economic activity and spare capacity can increase

[1] According to Canterbery (2001), inflation can also include structural, and expectational. Although it is useful to have such delineation, it is often difficult to identify in practice (Canterbery, 2001).

production and employment with negligible increases in price levels. Price increases will not be negligible when an economy is operating at levels of economic activity close to or at its capacity. When an economy is close to or at its capacity, increases in AD will not result in increases in production because as an economy approaches capacity, the firms will not be able to meet demand as there are limited resources available for production. There will be greater demand chasing a fixed supply. These bids increase the prices of the goods and services. Thus, any increase in AD will only result in increasing prices when an economy is close to or at its capacity. This is demand-pull inflation. Similarly, for an economy operating close to or at its capacity, production output is unlikely to increase. There are fewer resources available for production. The use of these limited resources is likely to come at a higher price as competition for the resources bids the cost upwards. This translates to cost-push inflation, in which changes to AS will only result in higher prices. An economy can also experience higher prices earlier when capacity contracts in the long run. This can occur when there is a reduction in the labour force, an aging population, or when productivity falls. Thus, cost-pull inflation can be attributed to decreases in AS, as well as to a contraction of the economy.

Unemployment and Inflation

In the short run, unemployment can be caused by a downward shift of AD or an upward shift of AS. In the long run, unemployment is greatly dependent on the production capacity of the economy. If there is no spare capacity, unemployment will rise as capacity is close to being fully utilised with no allowance for further employment. Unemployment can also rise when an economy faces real wages that are too high. Policies to increase AD will not reduce unemployment. Instead, policies should aim towards lowering real wages to reduce unemployment. Both inflation and unemployment are interdependent problems as they relate to the fundamental question of macroeconomics, that is, the aggregation of economic activity. In other words, they determine the degree to which productive resources are used for aggregate output in relation to potential output. Ideally, an economy should have zero unemployment and inflation within a range of between 2-3%, with a matching level of aggregate output. However, the reality is far from ideal. Unemployment and rising prices exist in all economies. High inflation will not be tolerated by central banks. They will take measures to curb inflation by slowing output growth and raising unemployment. Inflation targeting is a commitment by the central bank to maintain stability of the general price level. As long as unemployment is within an acceptable level and inflation is within a targeted band, both problems can be managed with stabilising policies. Stabilising policies help predict output growth and the corresponding price level changes, which are critical to a stable macroeconomic environment.

The relationship between unemployment and inflation can be explained by the Phillips curve – where there is an inverse relationship between the unemployment rate and the rate of inflation. That is a lower level of unemployment will bring about a higher level of inflation for an economy, and vice-versa. While this trade-off between unemployment and inflation holds true in the short run, it does not offer a comprehensive solution to the complex issues faced by economies in the long run. This is because prices are sticky in the short run and flexible in the long run. However, if this inverse relationship between unemployment and inflation is assumed to be stable, policy intervention in the form of monetary and/or fiscal can be used to stimulate an economy by controlling unemployment and managing inflation. A higher level of inflation can be tolerated as this would lead to a lower level of unemployment at equilibrium. An economy at equilibrium will display a gap from its steady state equilibrium. This gap is known as the income gap.

Level of Aggregate Output and Policy Interventions

Fluctuations in AD can lead to greater fluctuations in aggregate output, unemployment and inflation. There are stabilising policies that governments can undertake to manage AD (Stegman and Junor, 1993). The policies are aimed at stimulating AD during periods of high unemployment and acting to restrict AD when the economy is at its productive capacity and generating inflationary pressures. The discretionary fiscal interventions of expenditures and tax revenues are warranted by the government. Tax revenues are required to finance national defence, education, health care, and infrastructure. However, such direct government intervention may provide no sustainable reduction in unemployment because the effect of changes to the true structure and behaviour of the economy may take time. For example, when tax revenue is reinvested in the infrastructure of an economy, AD will increase due to increases in investment in the short term. However, the returns to the economy will only be felt in the longer term, when capacity of the economy is increased. Samuelson and Nordhaus (2001) attributed the shortcomings of fiscal intervention to timing, politics and macroeconomic theory. Timing refers to time taken to recognise a shock, to formulate a response, and for the legislative approval of a budget. Politics refers to the ease of cutting taxes as opposed to raising them. Lastly, macroeconomic theory refers to temporary tax changes that do not affect lifetime income. There is a built-in component of automatic stabilisers that can be used to stabilise the economy. These counter-cyclical effects are a result of fluctuations in the economy with no government intervention. When real output increases, government expenditure will decrease, and taxes will increase. As an illustration, a fall in unemployment reduces benefits spending, and this reduces the budget deficit during an economic expansion. A higher level of employment is likely to bring about a greater level of tax receipts and lower government expenditures. Economic growth is likely to be controlled as AD is likely to be reduced, minimising the risk of inflation. However, automatic stabilisers may not be as effective as previously thought because consumer-expectations and business'-expectations may change. External economic influences may lead to changes in expectations, especially if uncertainties and risks exist. Alternatively, the government can rely on the central bank to use monetary policy to address the stability of the economy. This is an indirect intervention through the use of interest rates, primarily to target inflation in the economy. There must be a right amount of monetary stimulus or restraint. For simplicity, this thesis assumes that interest rates are set by the central bank. This assumption is critical as Taylor and Williams (2009) found macroeconomic models of monetary policy evaluation could not reconcile the spread between central banks' interest rates and market interest rates set by commercial banks. Frank and Bernanke (2009) proposed that to make sensible policy, central banks must have an idea of the inflation rate they would like to achieve. Similarly, Chari, Kehoe, and McGrattan (2009) echoed that some form of inflation target with well-defined escape clauses is what most macroeconomists are comfortable with. The success of monetary policy depends on the policymaker's commitment and on keeping both interest rates and inflation low on average. Central banks announce a numerical target for inflation to increase credibility and better anchor inflation expectations. This keeps inflation within a band and helps to maintain a desired employment level. To ensure credibility of the use of monetary policy, central banks have been given more independence. They are insulated from short-term political considerations and allowed to take a long-term view of the economy (Frank and Bernanke, 2009). However, if the shock is of a supply side nature, monetary policy will not help with addressing unemployment because policies dealing with labour supply and productivity are not within the jurisdiction of the central bank. A fiscal-monetary mix can also be used, depending on the relative strength of the fiscal and monetary policies and their effects on the different sectors of the economy (Samuelson and Nordhaus, 2001). Thus, to manage AD fluctuations, fiscal and monetary policies or a fiscal-monetary mix can be used to keep AD and output at equilibrium.

When an economy is at its natural rate of unemployment, policies will have marginal or no influence on employment. Such interventions can only result in inflation (in the long run), generating further inflationary pressures. Given that the level of aggregate output is explained in reference to the natural level of output determined by the productive capacity of the economy, it is critical that the productive capacity of the economy be correctly determined. The productive capacity of the economy is dependent on the production process. The production function in most economic textbooks (Dornbusch, Fischer, and Kearney, 1995; Frank, 2003; Pindyck, Rubinfeld, and Koh, 2006; Mankiw, Wilson, and Quah, 2008; Blanchard, 2009; Frank and Bernanke, 2009) considers labour (L) and manufactured capital (KM) to be the only factors of production. The price of labour is the wage paid to each unit of labour. And the amount of labour can be determined through demand and supply in the labour market. KM refers to goods used in future production. They can be priced as rent, assuming that it is not owned and supply is fixed. With technological advancement, the rent can be discounted for depreciation. Thus, both L and KM can be priced easily through their respective markets. However, production does not rely only on L and KM but also on the natural environment. For example, air, land and water are essential requirements for the production process.

Internalisation of KN

There are a few authors who have considered natural environment inputs to production. Frank (2003) discussed natural resources as inputs in production. The discussion was focused on the awareness of renewable and exhaustible (non-renewable) resources, and the transition from exhaustible to renewable energy sources. Frank's collaboration with Bernanke in a later textbook (Frank and Bernanke, 2009) presented the production function to include technology and land. However, the numerical illustration focused only on L and KM. Mankiw, Wilson and Quah (2008) included L, KM, natural resources and technology in their production function. Similar to Frank and Bernanke (2009), the numerical illustration focused on L and KM based on their returns to scale. As per Frank (2003), their natural resource discussion was limited to renewable and non-renewable resources. Most authors discussed the natural environment but did not proceed further to incorporate natural resources into the production function. They stopped short of accounting for natural resources and attributed economic growth to non-resource factors. Although resources are recognised as a necessity for production, the amount of resources used can be small because L and KM can be substituted in sufficient quantities. Perhaps, a justifiable analysis of the natural environment as inputs to production was made by Samuelson and Nordhaus (2001). They divided factors of production into three categories: land, L, and KM. Land and L are the primary or original factors of production. Land can be a derived demand as it depends on the product produced. KM was added only as the produced factor of production and can be categorised as structures, equipment, and inventories. A United Nations report published in 2012 identified nature (as well as capital and labour) as a capital and it includes land, forests, fossil fuels and minerals as a wealth asset. Thus, investments towards production should consider natural capital as a factor of production.

If the production process takes into consideration the natural environment, using up more of the environment capital will reduce the capacity of an economy. The economy will contract, resulting in greater unemployment at current market wages. This overstates the capacity of the economy as the true capacity of the economy has been appreciated. In turn, this will generate inflationary pressures as there are fewer resources to go around within the economy. Hence, an inclusion of environmental capital in the standard macroeconomic framework might generate greater unemployment and higher prices.

Consider a vineyard operating in a wine county. The grapevines (roots) require water from the soil to grow. Minerals from the water are absorbed by the vines, providing the necessary nutrients for growth. Thus, water acts as both a sink and a source. The ideal water required is nature's water and explains why a lake or a water catchment is located not far from the vineyard. The first step in winemaking is the harvesting process. Grapes, twigs, and vines have to be separated as only the grapes will be crushed for their juice. The twigs and vines can be returned to the soil as organic fertilisers. They serve to retain moisture in the soil. This reduces the water intake (from the water catchment) required by the grapevines. It is the inorganic fertilisers that pollute the water and the polluted water will in turn affect the growth of the next bunch of grapes. This will affect the quality of wine and bottle sales for the vineyard, and thus may result in a lower quantity of wine being bottled. In addition, these combined factors can lead to the closure of the vineyard in the long run with unemployment for the vineyard staff; no doubt a simplistic example but the potential of such a scenario becoming a reality cannot be disregarded if the environmental capital (the water catchment in this example) is not properly maintained.

3. CONCLUSION

Managing the economy involves concern about the level of aggregate output, unemployment, and inflation. These are the concerns to promote economic growth and further raise the material standard of living. Lately, this also involves taking steps to ensure that the malfunctioning of the natural environment does not impose great costs on and disruption to the economy. Macroeconomic policies aim to stabilise an economy in the short run and to maintain a steady state of economic growth and employment in the long run. Traditional methods of macroeconomic policy formulation consider the state of an economy but exclude the state of KN. Therefore, the challenge of macroeconomic frameworks will depend on the recognition afforded to KN aside from the traditional factors of L and KM to ensure the effectiveness of policies. The standard frameworks discussed above pave the way for alternative frameworks in the following section. There are challenges to the standard frameworks, which are demonstrated in the following literature review of EM.

This thesis is structured as follows. The first chapter provides an introduction to this study and a synoptic description of the standard macroeconomic framework and relative implementation of policy practices. The next chapter addresses the challenges of the standard frameworks; these challenges are demonstrated in the literature on environmental accounting and environmental-macroeconomics (EM). This literature is classified on the basis of materials that (a) focus on concepts and paradigms and (b) extend the conceptual / dogmatic premises to empirical applications. Chapter Three addresses questions that arise in the context of recognising environmental capital (KN) in the standard macroeconomic framework. These questions help to pave the way for proposing an alternative EM framework for policy analysis. Chapter Four addresses the measurement of KN and its utilization with reference to selected Organisation for Economic Co-operation and Development (OECD) economies, namely Australia, Canada, France, Germany, Japan, Korea, Mexico, New Zealand, Norway, United Kingdom and the USA. Chapter Five provides a comparison of the economies' steady state equilibrium between the standard macroeconomic framework and the EM framework. Chapter Six presents the methodology for analysing how macroeconomic goals are affected by the steady state equilibrium. This is followed by a discussion of significant findings of policy ranges when the EM model is used as opposed to the standard macroeconomic model in Chapter Seven. Finally, this thesis concludes with a summary of the research and presents the directions for future research.

Chapter Two – Literature Review of Environmental-Macroeconomics

1. INTRODUCTION

This chapter presents a literature review of Environmental-Macroeconomics (EM). The relevant literature on this topic may be broadly classified into two groups, namely:

I. Literature on environmental accounting, and

II. Literature on EM analyses

The chapter will begin with I. followed by II. Under II., there are two sub-categories, namely; conceptual / theoretical analyses and applied policy analyses.

2. LITERATURE ON ENVIRONMENTAL ACCOUNTING

As Hanley et al. (1997) stipulated, the need for EM analyses stems from the fact that the economy and the natural environment are linked to each other in the following two ways: 1) environmental capital (KN) acts as a source of inputs, and 2) KN acts as a sink for economy's waste. This close inter-relationship between the economy and the environment suggests that the environment cannot serve both as a sink and a source simultaneously. The first law of thermodynamics states that matter cannot be created nor destroyed; it can only be re-arranged (Marshall, 1891). Matter is re-arranged as the environment provides material for energy input (point 1) and absorbs waste (point 2). Energy is transformed from a state of low entropy (high energy) to that of high entropy (low energy) to do work. This is the second law of thermodynamics. When an economy consumes, matter goes through phases of arrangement and re-arrangement. These phases use up the available energy levels with no recycling option. Consumption involves a rearrangement of energy within the economy as well as the environment (Daly, 1997). As a result of this non-recycling, some of the matter will become residual waste. The combination of the two laws results in absolute scarcity of resources (Daly, 1991)[2]. Such scarcity implies that the environment must be used in an efficient manner to allow for sustainability.

The close relationship between the economy and the environment suggests that environmental damage caused by the economic system must be constantly managed and mitigated. But most of the literature has been predominantly based on microeconomic analyses. Microeconomic analysis is about optimization; that is, maximizing benefits and minimizing costs. For example, Dixon et al. (1997) presented areas where microeconomic analyses are applied through the improvement of the pricing system and correcting market failures using various valuation techniques; and the damages they do to the environment[3]. Optimality indicates how much of an economy's resources to consume and at what prices. Markets can solve allocation problem by providing symmetric information and regulated incentives. But the problems of optimal scale and optimal distribution are not solved as there are conflicting values of allocation, distribution and scale (Daly, 1996). In addition, microeconomic analyses failed to account for the economic performance of the economy – which can only be achieved with macroeconomic analyses.

[2] Daly wrote on his blog http://www.neweconomics.org on the 8th November 2011 that the first and second laws of thermodynamics should be called the first and second laws of economics.

[3] Microeconomic analysis looks at a time period. This does not address inter-generational equity as future time periods are not considered.

However, even a comprehensive review of environmental economics by Cropper and Oates (1992) in the Journal of Economic Literature failed to include environmental considerations in macroeconomic analyses. The focus should lie in the analysis which can better represent the intimate relationship between the economy and the environment; that is, macroeconomic analyses. Beyond the standard macroeconomic indicators, the analysis should include the performance of the environment to demonstrate this intimate relationship between the economy and the environment. This was one of two concerns highlighted by Daly (1994). According to him, there are two concerns: 1) the relationship of the economy and the environment; and 2) the relationship of the economy to ethics. This review will focus on the former, the relationship of the economy and the environment.

Georgescu-Roegen (1971) and Daly (1977) argued that more economic growth would entail more production and consumption activities to satisfy human wants. Kolstad and Krautkraemer (1993) pointed out a dynamic link between the environment, resource use and economic activity. While resource use, especially of energy sources, yields immediate economic benefits, it also has a negative impact on the environment but this downside is observable only in the long run. England (2000) explored the relationship between capital accumulation and economic growth and between capital accumulation and the natural world. He found that modern growth models were silent about the natural foundation of production. Land was not considered as an asset, raw materials were not considered as commodities, and no energy was required to drive the production process. However, if an economy is to grow by consumption, nature will play an important role.

Growing by consumption may not necessarily represent a greater level of well-being. Manner and Gowdy (2010) explored the usage of consumption as a proxy for well-being, but challenges by behavioural research have found that well-being is a function of much more than economic consumption. There are other factors that affect well-being. It has been found that consumption is the principal driving force behind environmental impacts (Rothman, 1998). Hence, economic growth (at least through consumption) has failed to explain well-being as well as the degradation of the environment. This may put a population's well-being at risk should the environment continue to be neglected as economies grow. However, the environment must be kept intact so as to provide future generations with a set of life opportunities undiminished relative to present opportunities (Howarth, 1997).

Vide paper by Boersema (2011), a simple explanation is that every person impacts the earth's natural resources to some extent. To achieve a sustainable world, population figures need to be stabilized at a given point. However, as people live longer due to better health care and services, the world's resources are straining to support an aging population (Boersema, 2009). To be sure, the world's population cannot continue growing indefinitely. And Boersema (2009) argues that there is a limit to population growth, in terms of the earth's capacity. The danger of the earth's capacity being exceeded in the future due to population growth cannot be discounted. In fact, in Case, et al. (2005) the argument is that population pressures have built up to the point that land has run out! An earlier argument from Ehrlich (1968) is that population size is the most significant factor in determining environmental impact. He had even argued for a formula in the following form:

Environmental Impact (I) = People (P)*Measure of Affluence (A)*Technology (T)

According to Dietz & Rosa (1994) and Boersema (2009), this is an analytical formula which describes the interaction of the variables in a quantitative way. However, this formula (like many others) is not without limitations.

Arrow et al. (2004) reconciled the conflicting intuitions of consumption (towards economic growth) by using both ecological and economic insights to raise questions that might not have been raised. Consumption increases the use of natural resources, reflecting a higher demand from a growing world population. It also reflects growth, or per capita output, and consumption. According to Arrow et al. (2004), with the increase in the use of natural resources, an increase in investments has also been witnessed[4]. Despite stresses on the natural resource base, such investment was necessary to ensure higher (or at least similar) real living standards in the future. In addition, there are other ways to compensate for the diminishing of natural resources, for example, through incremental boosting of manufactured capital and human capital, and technological advances. Therefore, Arrow et al. (2004) argued that it was unnecessary to account for the environment in macroeconomic frameworks when an economy is growing. After all, there are other measures; such as the ecological footprint, that measures the resources necessary to produce the goods and services an individual or population consumes. Notwithstanding the ecological footprint being a plausible measure for sustainability, Fiala (2008) critiqued it as an ineffective proxy and argued for better measures of sustainability. His focus was on abandoning

[4] The implicit assumption is that the entire utilization of natural resources goes to investment (I). However, a large part of this utilization also contributes towards consumption (C).

composite indicators and directing examination of two issues for sustainability, namely land degradation and carbon dioxide aggregation. Despite his emphasis on land degradation and carbon dioxide aggregation, it is neither the degradation (consumption) nor the aggregation (production) that derives satisfaction. According to Boulding (1949), satisfaction occurs when there is no degradation or aggregation, that is, when an economy has reached a steady-state equilibrium. Hence exponential growth cannot go on forever in a finite world (Boulding, 1966).

Steady state, as defined by John Stuart Mill (1857), is a "stationary state" of zero growth in population and physical stock coupled with a continuous improvement in technology and ethics. Steady state is not an end in itself but merely a situation with restriction on any further growth in population and production. In Daly's (1996) words, this is the concept of sustainable development. Once growth is allowed to progress beyond sustainable development, there will be two immediate trade-offs: 1) regeneration of renewable natural resources of an economy; and 2) the environment's assimilative capability of waste absorption. This demonstrates the close-knit relationship between economic activities and the natural environment. As discussed earlier, Daly first highlighted this in 1994 – the natural world is an ecosystem that is finite, non-growing and materially closed (Daly, 1996). Arrow et al. (1995) led ten other academic economists to make the similar point that the environmental resource base is finite. In addition, they made two other points: there are limits to the carrying capacity of the planet; and economic growth will not cure falling environmental quality. This close-knit relationship demonstrates that the environment acts as a sink when economies grow and that environmental degradation is a result of economic growth. This is a contradiction to a later claim by Arrow et al. (2004) that there is no need to account for the environment in macroeconomic frameworks when an economy is growing, but rather the environment only needs to be accounted for at steady state.

The World Bank (according to Daly) has acknowledged conflicts between growth and the environment; growth being seen as the solution to poverty, and environmental degradation being viewed to be mainly a consequence of poverty. By failing to account for the environment, economic growth may have been misrepresented. However, one cannot deny that political influence may make ignorance of the environment a matter of convenience that can be further aided by a continual denial in the accounting for the environment in macroeconomic frameworks.

Daly raised a key point during his farewell speech at the World Bank in 1994, namely, that it is not always possible to measure and value environmental damages. Any effort in measuring and valuing environmental damage – to provide information on the interaction between the economy and the environment so that natural and environment resources can be more effectively managed (Sève, 2002) – although recognised in national accounting systems, tends to be incomplete with respect to environmental issues, as illustrated in the following accounting systems: 1) the United Nation's System of National Accounts (SNA), and 2) Natural Resource Accounting (NRA) / Green Accounting. NRA measures environmental degradation and resource depletion, and the results obtained are used to adjust the conventional Gross Domestic Product (GDP). However, data availability and issues relative to this method of estimation remain a cause for contention (Statistics New Zealand, 2002). In addition, Harris and Fraser (2002) found that various models of work in this field are not well-integrated, linkages barely exist in some and in others there are significant conflicts. There is an increasing disparity between what matters to people and what is included in or excluded from GDP. Hence, any further increases in GDP (growth), unless carefully managed, will only make matters worse (Booth, 2004).

The section which follows will focus on United Nation's SNA as it has shown significant progress towards accounting for the environment since its inception in 1953.

United Nation's System of National Accounts

The SNA was officially endorsed in 1953 for international use. The earliest SNA was worked out by the United Nations after World War II to estimate national income through the medium of national accounting. It consisted of an integrated set of macroeconomic accounts, a balance sheet and tables based on internationally agreed-upon concepts, definitions, and classifications and accounting rules (United Nations, 1993). Because of its nature at inception, it serves to measure the level of employment and the value of output produced. This is one way to track how an economy has performed and progressed over time. It also serves to forecast and project the state of an economy in future time periods. Various revisions to the SNA have been made, resulting in a specific version in 1968, another version in 1993, with the latest updating taking place in 2008. As it is the most comprehensive macroeconomic standard, it also serves as the main reference point for statistical standards of balance of payments, financial, and government finance statistics. However, the SNA up to now has given little or no information on how the environment is affected as a result of economic growth. Hecht (2005) offered a summary as to why the SNA must be reviewed to accommodate environmental degradation as follows:

i. Natural assets, such as forests, fisheries, and land are treated differently from manufactured assets such as factories and machinery. Similar to manufactured assets, depreciation should also be taken into account for natural resources, as they are continually being used up during economic growth. This view stemmed from an earlier approach by Repetto et al. (1989, 1991), in which depreciation of natural capital was deducted from net national products

ii. Defensive expenditures [5] (expenditures on environmental protection) should not contribute to GDP as such expenditures do not add to well-being. It is an expenditure that prevents the population from being worse off. Daly (2007) shared the same view

iii. GDP and other macroeconomic indicators should be modified to accommodate the measurement of welfare

iv. The value of environmental goods and services should also be included, even though some of these goods and services may not have been transacted through a market

[5] On the same count, expenditures towards health, social, and welfare also do not contribute towards GDP. These are expenditures that prevent the population from getting worse off. But such expenditures seemed to be less scrutinized compared to expenditures towards the environment.

As a consequence of the SNA being deficient with regard to information on economic growth vis-à-vis the environment, the revised Handbook of National Accounting: System of Integrated Environmental and Economic Accounting (SEEA-1993) was an attempt at environmental accounting. SEEA is a satellite system of the SNA as it brings together economic and environmental information to measure the contribution of the environment to the economy and the impact of the economy on the environment. The discussion of concepts and methods for SEEA-1993 did not come to a final conclusion and was left as an "interim" version. According to Hecht (2005), this was because it was too conceptual to be implemented with ease. In addition, the discussion for revising the SEEA-1993 failed to involve key stakeholders. The key stakeholders (who were excluded) included the economists who had done significant conceptual work on environmental accounting, environmentalists who pushed for the inclusion of environmental accounting, and representatives from the developing world (Hecht, 2005). In response to increasing policy demands, the United Nations Statistical Division agreed to mainstream environmental-economic accounting, and a revised satellite system was developed a decade later, in 2003. The revised SEEA-2003 will be the statistical standard for environmental-economic accounting as SNA is the statistical standard for economic accounts (United Nations et al., 2003). The SEEA parallels the SNA structure but builds on it by constructing both physical and monetary accounts to address environmental issues as well as forecasting the future availability of environmental resources (Hecht, 2005). It has been designed for decision-making and policy-making across industrial structures and at different stages of a nation's economic development. More importantly, it has been geared towards international recognition, similar to how the SNA was originally conceived. Work is currently in progress to revise the SEEA-2003 version, with a timeline for publication in 2012 (United Nations et al., 2008). Based on the SNA-2008, the goals (selected) of the SEEA are to encourage the adoption of standard classifications in environmental statistics, bring a new dimension to environmental statistics by applying the economic accounting traditions linking stocks and flows, and identify use and ownership of, and hence responsibility for, environmental impacts. Furthermore, there must be some form of accounting for how environmental degradation impacts the national income of an economy. A chapter was devoted to this in SEEA-2003, and the SNA-2008 considered this to be one of three main sections when accounting for the environment. The following discussion examines the revised SEEA-2003 in detail.

According to the revised SEEA-2003, natural capital is generally considered to comprise three principal categories: natural resource stocks, land, and the ecosystem. Natural resources refer to resources drawn into the production process to be converted into goods and services. Land acts as a sink to absorb the unwanted by-products of production and consumption. The ecosystem serves as a habitat for all living beings. Solow (1974) argued that there is, in principle, no "problem" as produced and human capital can be substitutes for natural capital. In this instance, income generated is constant, and natural capital can depreciate subject, however, to being replaced by other forms of capital. Besides Solow, others have also argued that the extent of substitutability is limited (Hecht, 2005). This group of researchers has argued that capital will only be of value when complemented with another form of capital. In such instances, capital is maintained independent of other capital to ensure that income generated is constant (when capital is used together). There is a set of "precautionary principles" to ensure that capital is maintained (Hecht, 2005). Firstly, renewable resources should not be used in excess of their natural regeneration;

secondly, non-renewable resources should only be used prudently to ensure that future generations continue to have access to the same resource; thirdly, sink functions should not be used beyond their assimilative capacities; lastly, environmentally deteriorating activities should be avoided.

Notwithstanding the inclusion of contribution of the environment to the economy in the revised SEEA-2003, there are still some issues associated with measuring the environment that require further fine-tuning. Some of these issues are highlighted in selected chapters of the revised SEEA-2003 and will be discussed in turn with the wider scholarly literature.

Chapters Three and Five of the revised SEEA-2003 deal with the modus operandi for accounting for natural resources, economic activities and products related to the environment. When a resource is extracted and used to produce a good or service of economic value, an identity can be derived to account for the flows. Recognising the environment can also be represented by expenses associated with maintaining the environment. Accounting for the flows recognises the environmental impact, but it fails to account for reductions of the environment's assimilative capacity as a sink. This is not in agreement with the third point of the "precautionary principles" from Hecht (2005); that is, not using the environment sink beyond its assimilative capacity. In Chapter Seven, asset accounting can be practiced by measuring the stock of the asset at the start of an accounting period and at the end of the period. An asset is usually productively limited to one particular usage at a time, notwithstanding its capacity for use in competing ways. For example, if water were used as a source for drinking, the assimilative capacity for water as a sink would be reduced.

The discussion then revolves around: When should an asset be used for income generation, and when should the same asset be preserved for maintaining the sink? This is a critical question as assets are often scarce and have competing uses. Income has traditionally been used to measure an economy's well-being, besides being a guide to the maximum amount of consumption by an economy without compromising future expenditures. To ensure that the income is not fully consumed, depreciation is subtracted from income to obtain net national product (NNP). One consideration for such subtraction is the depletion of natural capital (Daly, 1996). Natural capital can be defined as capital required for industrial production and can be categorised as non-renewable or renewable. Depleting the renewable capital means reducing stocks available for consumption. A reduction in consumption might possibly help to maintain the stock level, but this does not ensure a sustainable level of income. Depletion of the non-renewable resources means that the resource is not available for future consumption or usage. Extraction of non-renewable resources should not contribute to income as the resource will eventually be completely extracted, i.e. fully depreciated (Brekke, 1997). Ideally, there should be some form of measurement to account for its permanent loss, but the need to adjust accounts for environmental and ecological losses depends on the development stages of individual economies. Developed economies have liquidated most of their natural wealth in the developing process. Their domestic products are now derived mainly from secondary and tertiary production. However, developing economies would depend on primary production. Exchanges are made through the sale of assets, as opposed to value-added services.

Economies at their development stage will make no attempt to distinguish between renewable and non-renewable assets. Therefore, the discussion on whether it was income from revenue or income from the sale of assets (or an allowance for depletion) would not have been a priority.

When measuring the income of an economy, the SNA's model balance sheet recognises land, minerals, timber and environmental resource as economic assets included in a nation's capital stock but the income and product accounts do not (Hanley et al., 1997). Hicks (1946) defined income as "the maximum value which can be consumed during a week and still expect to be as well off at the end of the week as was in the beginning". El Serafy proposed the user cost approach to compute the Hicksian income. The "El Serafy Method" (first published in 1981) suggests that only part of the proceeds from the sale of resource assets can be considered income (El Serafy, 2002). His illustration was such that not all revenues accrued by oil-exporting nations can be calculated as income. After all, there is depletion to the stock of the asset – which is irreversible. And no allowance is made for that. Hecht (2005) made this similar point when considering resource accounting. As economies continue to grow and consume, the environment is degraded, and there is a need to account for this. The expenditure that goes towards protecting and maintaining the environment should only be considered once, as an earlier expenditure would have accounted for the degradation that has already occurred. In fact, it is also possible that expenditures to maintain the environment could contribute to further environmental degradation.

Price signals are typically used to aid in the discussion of whether an asset should be used or preserved. However, as Chapter Nine of the revised SEEA-2003 shows, the non-existence of a market and price implies that there is no procedure in place to measure the costs and benefits of using or preserving an asset. Market prices reflect the relative scarcity of individual resources but do not measure the absolute scarcity of resources in general. Hence, income derived in this manner does not necessarily correspond to well-being. Perhaps, a better choice for an objective measurement of well-being might be consumer surplus. Consumer surplus is the difference between the maximum price an individual is willing to pay and the price paid. Unfortunately, consumer surplus is not included in the calculation of National Income Accounting. In the absence of markets, there are other factors that can be considered to contribute to national income. For example, the life of an asset, the resource rent it provides, and the discount factor that can be used to value future returns at the present time.

The challenges faced when measuring national income are no different from those for measuring environmental degradation. Valuation techniques (with time taken into consideration) may be a better estimation than the use of traditional statistical methods because degradation is a cumulative continuing process in a time continuum, not a one-off occurrence in one particular time period. An option is to base such valuation of the asset on the principle of replacement cost, or the willingness to pay (WTP). The replacement cost is simply the cost of replacing a damaged environmental asset, and WTP is the amount to be paid for an environmental benefit. In both instances, there is no market to attach a price to the cost or benefit, and even if a market exists, the economic framework may not always be practical for valuation (Ison, Peake, Wall, 2002). A no market scenario seems a convenient excuse not to account for and value a natural resource. But the absence of a market is only one of many considerations. For example, there are other considerations, such as valuing a mobile underwater resource (fisheries) or considering if there is a spatial component provision (land and water) (Hecht, 2005). A discussion of a popular valuation method is illustrated in the following as it provides a "shadow price[6]" for resources that are non-market tradable.

When one considers the environment as a consumption good, valuing environmental damages based on WTP is termed the contingent valuation (CV) method. The CV method is the most widely used method as other valuation methods are unable to identify and measure passive or non-use values of biodiversity (Nunes, can den Bergh, 2001). This is evident with its application in various scenarios of environmental valuation (Carson, 2007). According to Thampapillai (2002), it is a popular method because it is easy to apply and has a wide range of contextual applicability. However, the estimation of WTP can demonstrate biasness, such as in the case of preserving the Kariba lake shore in Zambia (Thampapillai, Maleka, Milimo, 1992); in this example there were respondents who were willing to contribute in excess of 50% of their income, whilst there were others who were unwilling to contribute. Knetsch (1994) argued that the correct measure for CV should be the sum total compensated to individuals for the environmental damage. This is the willingness to accept (WTA), an amount which will normally be far larger than WTP. Outcomes of such nature demonstrate that WTP biasness may be inherent in nature, leading to inappropriate environmental policies and distorted incentives as losses are valued more than gains.

[6] Shadow price is the price of the factor of production when the market is perfect, for example when all resources are fully employed.

It is argued that loss schedules might be implemented faster, provide deterrence incentives, and predict incurable outcomes, and hence are deemed as more appealing and more just than dependence on rational behaviour. An earlier study by Sinden (1994) found that the estimation of values for un-priced goods and services usually meets several objections. However, valuations serve to account explicitly for factors that are otherwise overlooked, implicitly valued, and often wrongly valued. Thus, the consistency in the findings across the body of valuation studies adds more value than the findings from each individual study.

No depreciation estimate, even in terms of a universally agreed-upon valuation method, can be considered as truly accountable. It can be argued that the existence of a market may be the key as prices can be rightfully determined. However, the fundamental goal is to ensure that there is some form of allowance allotted to the depletion of natural capital in the existing SNA. Adjustment towards a measure of true income (sustainable NNP) is a good start towards subtracting expenditures that do not reflect any increase in the net product available for consumption without eventual impoverishment (Daly, 1996).

According to Daly (1996), the error of implicitly counting natural capital consumption as income is customary in three areas: SNA, evaluation of projects that deplete natural capital, and international balance of payments accounting. The first area is on its way to being “greened”. Daly’s (1996) suggestion is to restructure national accounts to measure the costs and benefits of growth, such that comparison is allowed for finding the optimal scale of the macro economy. However, optimality is based on the assumptions made in the economic calculations for integrating the environment (Amin, 1992). Although Stavins (2007) encouraged market-based environmental instruments to test whether social benefits exceed total social costs, there are differing views. Specifically, Daly (1991) has suggested that markets can function to better allocate resources only through the provision of necessary information and incentives. This is because incentives or punishments can alter and drive behaviour, and markets do not solve the problems of sustainable scale (this is not widely appreciated) or optimal distribution (this is widely recognised). Hence, the challenge is to determine how to internalise external environmental costs and arrive at prices that reflect the full social marginal opportunity costs. Stimulating growth beyond a market-determined level makes macro-level comparison of costs and benefits necessary because application of public policy to stimulate aggregate growth must depend on a comparison of costs and benefits at the macro level, and the social benefits of growth must exceed social cost. The second area underscores the need to count "user cost" as part of the opportunity cost of projects that deplete natural capital / sink capacity. As such, the true rate of return on a project would be calculated on the basis of the income component from the sale of depleted natural assets as net revenue. The third area deals with non-sustainable exports as sales of capital assets and not simply as export income. Nations that export natural capital may seem to have a surplus when, in fact, they have a serious deficit. Thus, Daly suggests that instead of one account, GNP, there should be three accounts for each basic magnitude: a benefit account to measure the value of accumulated services; a cost account to measure the value of depletion and pollution; and a capital account as an inventory of the accumulation of stocks for the economy.

Chapter Ten of the revised SEEA-2003 examines environmental adjustments to the flow accounts and demonstrates how depletion and degradation of environmental assets can be incorporated into GDP – "greened-economy modelling". Consumption of fixed capital is deducted from GDP to give a measure of net domestic product, thus, preserving a capital base. In line with preservation, a similar deduction should also be considered and made towards the consumption of natural capital. The controversy lies in the discussion on valuing non-priced degradation. An easy solution is to account for the physical quantity as opposed to monetary valuation. However, do all forms of degradation require valuation? Thus, accounting for the degradation can only be carried out when it is clear what needs to be counted. The incorporation of adjustments for degradation is still a work-in-progress, and it is this calculation of the adjustments that continues to be in debate.

Although the SEEA-2003 (issued by the United Nations, the European Commission, the International Monetary Fund, the Organisation of Economic Cooperation and Development, and the World Bank) represented a major step forward in the development of environmental-economic accounting, it did not provide unique recommendations to several issues. See the list of issues pertaining to the revision of the SEEA-2003 in Appendix 2.1. As Hecht (2005) suggested, SEEA was developed parallel to, and aims to be compatible with, the SNA framework. It is unlikely that the SEEA is adequate for green macroeconomic indicators measurement. Hence, Hecht (2005) proposed a range of measures that go beyond the SEEA and SNA to supplement the conventional macroeconomic indicators to capture output, welfare and sustainability.

The above discussion on selected chapters of the revised SEEA-2003 hopes to emphasize some of the issues which need to be considered before further progression. An Indonesia example by Repetto, et al (1989) showed how the standard income could continue to rise when the natural resource is being degraded; unless natural resource stock is taken into account. And the OECD has not fully reconciled the measurement and accounting of KN in GDP. Even though there are significant gaps to be filled, accounting for the environment has certainly shown progression as it is now being considered for the mainstream. However, debates continue and viewpoints differ for the accounting of environment. There is no one complete universal system which addresses the urgent need of measuring and accounting for environmental damage.

There have been a few noticeable attempts to measure and account for the environment. France attempted the most ambitious accounting system to date. That is patrimony accounting, which encompasses the three basic dimensions of natural environment; economic, ecological and social. President Clinton had also committed resources for developing environmentally adjusted accounts during his term. But like France's initiative, it did not enjoy implementation success (Dixon et al., 1997). Statistics Netherlands (2009) used the future-oriented approach – also known as capital-based approach to measure the natural resources (one of four themes; the other three being economic, human and social) available to a society. However, as Stiglitz, Sen and Fitoussi (2009) described: The issue is indeed complex, more complex than the already complicated issue of measuring current well-being or performance[7].

[7] According to Stiglitz, et al. (2009), much progress has been achieved in the past two decades on measuring environmental conditions and their impacts. There is a range of environmental indicators

Although there continue to be hurdles, several economies remain persistent towards a sustainable measure, for example European Commission, Norway and India. Following the United Nations Climate Change Conference in Cancun (December 2010), India plans to report, by 2015, GDP which takes into account environmental degradation[8]. In Norway, every Ministry separates their expenditures related to the environment – this is the Green Budget in the State Budget. The private sector is also required to incorporate green expenditures or investments (Muller, et al., 2011). And the European Commission will adopt a proposal to introduce the first ever Europe-wide "environmental economic accounts[9]".

Perhaps the most ambitious attempt to date is by Muller, et al. (2011). This is summarised as follows. The literature for the measurement of the environment has been focused at valuing water, forest, minerals, and pollution. Muller, et al. (2011) seeks to present a framework to integrate external damages (emissions are valued by the damage they caused) into national economic accounts. National economic accounts are based on the principle that they cover market activities. External effects are activities that are by definition excluded from market transactions. This study conducted by Muller, et al. (2011) differentiates by estimating the value of air pollution emissions, rather than simply reporting the quantity of emissions. In line with the discussions presented above, Muller et al. (2011) argued that traditional accounts do not measure externalities to non-market sectors; therefore, net national

---

which can be used to measure human pressure on the environment, responses towards environmental degradation, and state of environmental quality. However, existing indicators continue to be limited when measuring perspectives on quality-of-life. For example, premature deaths from air pollution, lack of access to water services, and damages from natural disasters. These indicators ought to be holistic and incorporate the effects that can vary across groups of people.

[8] http://www.bloomberg.com/news/2010-11-30/india-plans-to-include-environmental-costs-in-gdp-data-update1-.html

[9] http://euractiv.com/en/sustainbility/lawmakers-back-creation-eu-green-stats-news-499635

output is overestimated. Their concluding statement is a very fitting one. It goes: *While private scholars can make provisional estimates of the present kind, a full set of accounts needs the full-time staff, professional expertise, and access to proprietary source data that only a government agency possesses* (Muller et al., 2011). There are many areas where economic valuation of environmental impacts should be improved. This will help to measure and value elements of improved human welfare and progress that cannot be captured by GDP alone (OECD, 2012).

As a concluding illustration to this accounting section, consider the context of natural disasters. Natural disasters are becoming increasingly prevalent. Disaster is not a result of nature or an act of god; rather, it is the result of human actions. Take, for example, the demand for wood-based products (consumption), which causes deforestation. Deforestation can result in landslides and eventual loss of lives. This production decision has exerted stress on nature. This decision considers labour and machinery required to produce the desired output, but it does not take into account the natural environment as a source of input. Cannon (1994) attributed this to nature not being adequately integrated into social and economic systems. A technical explanation given by Hecht (2005) is that conventional accounts include only the marketed forest products that have a price, for example, timber. Consumers acquire the wood-based products, but the environmental sink loses its capability as a result of fewer trees. Hence, even if accounts were constructed to value the natural capital, it would not be easy to evaluate the natural capital (Daly, 2007). A successful development of national green accounting framework must lead to the development and application of EM policy models. Models do not forecast but rather provide an insight into how economies can develop. Internalising environmental costs will affect an economy's income; thus, it is best achieved with macroeconomic analyses.

3. LITERATURE ON EM ANALYSES

There are perhaps two sub-categories that deal with the application of concepts for EM analyses. In addition to the two sub-categories, policy intervention will also be discussed in this section.

A. Conceptual / Theoretical Analyses

B. Applied Policy Analyses, and

C. Policy Intervention

A. Conceptual / Theoretical Analyses

The conceptual / theoretical analyses are centred on tools of inter-temporal dynamic analyses, such as optimal control theory, difference and differential equations and dynamic programming. For example, see Munasinghe (2001) and Dasgupta, Kristöm, and Mäler (1994). The main difficulty with this literature is that they deal predominantly with specific exhaustible or depletable resources and not KN in an aggregate sense. That is, they do not treat KN as analogous to manufactured capital stock. Daly (1991) identified this weakness as an empty box in macroeconomic analysis.

Daly's (1996) argument was aimed towards the development of EM, where natural capital has replaced human capital as the limiting factor over time (See Figure 2.1). Thus, policies should be geared towards maximising natural capital's present productivity and increasing its future supply. This implies that measurement of income should include investment in natural capital, therefore, maintaining the natural capital as priority. To maintain the natural capital, there must be continued investment. This is because the value of investment will fall over time. There must be some form of allowance that takes the depreciation of the natural capital into consideration.

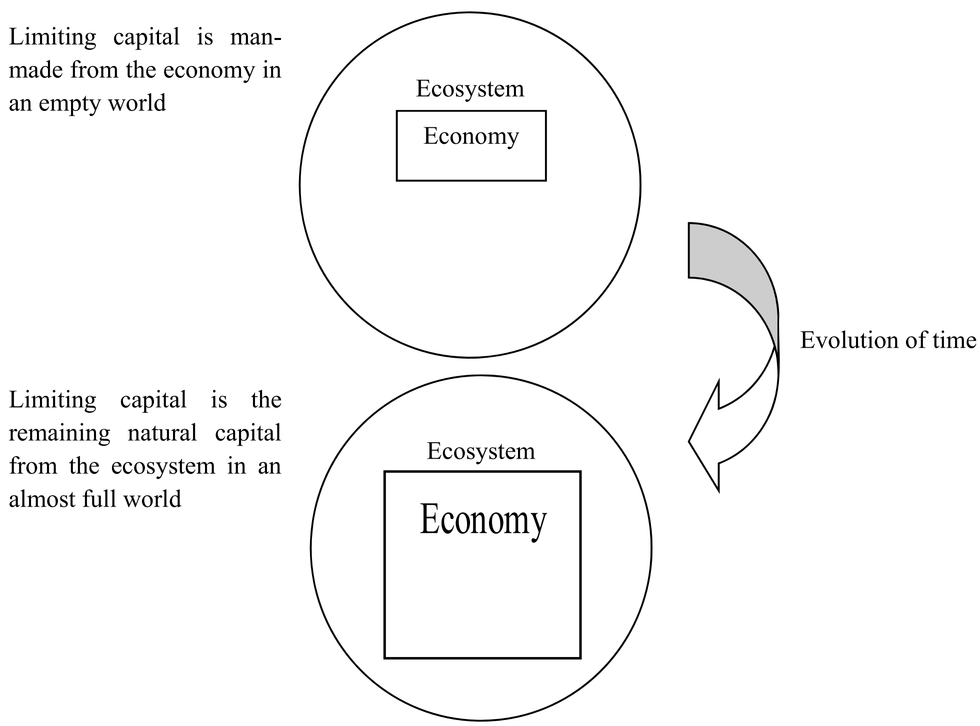


Figure 2.1[10]: From Human Capital to Natural Capital

[10] Adapted from Daly (1996), Beyond Growth, Beacon Press Boston

For this allowance to be fully captured in income measurement, there must be a price as well as a volume of exchange attached to the natural capital. Often, this is not a simple task. Let's first consider the volume of exchange. The volume of exchange can be accounted for by looking at the interaction between different economic models, that is, micro, macro and environmental. Firms and households (micro) operate within the aggregated (macro) economy. An aggregated economy operates within the natural ecosystem and is considered a sub-system (See Figure 2.1). The sub-system depends on the natural ecosystem for both its sink and source functions. EM would focus on the volume of exchanges that cross the boundary between the sub-system and the natural ecosystem. Thus, when one compares EM with macroeconomics, the focus is on the volume of transactions rather than relative prices (Daly, 1996). When it comes to prices, it is about internalising the external environmental costs to arrive at prices that fully reflect a socially optimal marginal cost. The natural ecosystem refers to the environment that living organisms interact and live in. It encompasses the air, soil, sunlight, and water. These are public goods without any property rights assigned. Consuming one more unit does not reduce the amount available for consumption (non-rivalry) and does not exclude (non-excludability) another individual from consuming. There are two challenges here. Firstly, it is not easy to arrive at a mutually agreeable price as there is obviously a market failure. Secondly, the range of the natural ecosystem means that one price for all will not accurately reflect the socially optimal marginal cost. The challenge is compounded as there are different measurement methods[11] for each of the natural ecosystems.

[11] According to the Australian School of Business, there are around 20 different methodologies for each level of water measurement alone.

Stiglitz, et al. (2009) argued that placing a monetary value on the natural environment is often difficult and separate sets of physical indicators will be needed to monitor the state of the environment. This is in particular the case when it comes to irreversible and / or discontinuous alterations to the environment. In addition, they deemed that climate change (due to increases in atmospheric concentrations of greenhouse gases) is special in that it constitutes a truly global issue that cannot be measured with regard to national boundaries (Stiglitz, et al., 2009).

Measurement and valuation of the environment have always been the central challenge when affording recognition to the natural ecosystem. Methods of valuation are questioned as there is neither an agreeable way nor a universal approach. In the interim, the search and use of proxies take precedence as time is running out. For ease of convenience, the natural ecosystem can be generically referred to as KN. One way to internalise environmental costs is made through the AD-AS model (Thampapillai, 1993). This model encourages the development of "environment saving technologies" by including environment in the production function. This was further evident in Thampapillai and Hanf (2000), where it was found that a reduction in KN reliance required technological improvements in utilising the environment as a capital. Such an effect was more pronounced when KN was incorporated into the production function. Thus, when the sustainability and non-substitutability of KN are recognised, all rents owing to the entire stock of KN need to be set aside as a depreciation allowance. The depreciation allowance was found to be the value that overstates the performance of an economy when KN is aggregated (Thampapillai and Thangavelu, 2004). This finding can be seen as a response to omitting KN from the production function in contemporary economics, where technology can be used to persistently offset the scarcity of KN (Thampapillai, 2008).

However, investing in environmental technologies does add to AD expenditures, which can potentially expand an economy's capacity. Moreover, policy decisions should be based on income domains that do not exceed the productive capacity dictated by KN (Thampapillai, 2008). This was illustrated with respect to Australia – a country that has reasonable compliance to environmental standards but with the policy domain significantly misplaced. The original policy domain, as opposed to the policy domain dictated by KN, would have only considered labour and capital as the standard inputs to output production (Solow, 1956). It was also safely assumed that both labour and capital could be easily substituted (Todaro and Smith, 2002). Such a policy domain renders a false economic equilibrium as production takes place with nature in the backdrop. If an economy driving towards economic growth continues to embrace the original policy domain, policies will continue to be incorrectly implemented.

There has been a noticeable change in perception as the continued neglect of the role of nature in the production for economic growth is progressively being overcome. This is evident by more eco-friendly, or "green", buildings, more initiatives towards sustainable living, eco-tourism, and a greater awareness towards environmentally friendly consumption goods and services. Indeed, economic growth generates environmental pressure. Environmental improvements have been reached in agriculture, industrial production, energy production, household energy use, food supply and waste removal.

Environmental stewardship had been focused on the supply side, but the assignment of environment stewardship is now shifting to the demand side, where responsibility resides in the consumers. This will be a lengthy transition as there may be incomplete information on the benefits and costs of environmentally friendly consumption (Welsch, 2009). In addition, Welsch (2009) found that people were evaluating their consumption levels relative to other people's consumption and their own past consumption. EM serves to understand the interaction between consumers, the economy and the environment to direct economies towards sustainability. The question points to the level of sustainability that can be attained. Therefore, policies should focus on restoring and maintaining KN to allow for future consumption. For example, the emissions tax and the tradable permit system [12] must be reviewed as they do not consider the accumulation of pollution loads but rather only the marginal loads. The emissions trading scheme seems to be accepted as carbon pricing seems inevitable, and reporting is likely to become a standard feature of a company's Annual Director Report (Harris and Brander, 2011). Thus, solutions to environmental problems require a review of the paradigm, that is, a fundamental transformation of the way individuals live their daily lives.

[12] On the 24th January 2011, Daphne Wysham, a fellow at the Washington-based institute for Policy Studies and founder of the Sustainable Energy and Economy Network commented that carbon trading is a "recipe for corruption" (Win, 2011). This is not untrue for one trades to gain, not to lose. Two days later, on the 26th January 2011, it was reported that Europe's physical carbon trading market suffered an attack from hackers, which crippled leading exchanges. The future of such trading market has been thrown into doubt (Stafford, 2011).

B. Applied Policy Analyses

An important aspect of applied policy analyses is the valuation of KN at the macroeconomic level. Repetto (1997) provided the basis of soil valuation and identified a link between KN and health. Health is used as a benchmark for the quality of the environment. Mendelsohn (2002) and Falk and Mendelsohn (1993) developed a basis and framework for air quality measurement. Vincent (1999), (2000) focused on forestry assessment. Applications of KN in macroeconomic framework are also evident in Thampapillai (2002), and Thampapillai et al. (2005), using the framework of the above three authors to develop policy analyses.

The inclusion of environment in macroeconomic frameworks was first proposed by Thampapillai (1993) to illustrate how environmental constraints can be explicitly incorporated into selected macroeconomic frameworks. An environmental cost function was developed and used in the adaptation of the following frameworks: the Harrod-Domar (H-D) growth model, the IS-LM model, aggregate supply, and the Keynesian expenditure (AD) model. Each framework has advantages and disadvantages.

The H-D growth model is one with emphasis on increasing savings to invest in efficient forms of capital towards economic growth. However, it does not consider interest rates, which are the price of investment. One model that considers interest rates is the IS-LM model. In this model, interest rates can shift decisions on current consumption and investment. Low interest rates would favour investment and do not contribute to sustainability because investment requires environmental inputs. The ambiguity of interest rates is attributed to the lack of information on environmental costs and the absence of such costs in National Income Accounting (NIA). An attempt to incorporate environmental measurement into macroeconomic analysis was made by Thampapillai and Uhlin (1994). Development of concepts and frameworks should begin by modifying the NIA to represent the role of the environment in an economy. One proposed example would be for KN investment and an allowance for depreciation to be included in net national product (NNP). This proposal justifies conceptualising the natural environment in the aggregate as a capital asset and treating it the same way as traditional building and machinery assets.

Thampapillai and Uhlin (1997) discussed the concept of considering the natural environment as a capital asset for sustainable income, incorporating the model justification in Thampapillai (1993) and the measurement of environmental costs in national income in Thampapillai & Uhlin (1994). This extended the treatment of the natural environment as an asset in a simple Keynesian (AD) framework towards the determination of sustainable income. Their analysis included the derivation of sustainable income paths and an evaluation of wages and technology / management policies. Both the derivation and evaluation jointly achieved full employment and sustainable income.

C. Policy Intervention

The OECD (2012) quotes, “without new policies, progress in reducing environmental pressures will continue to be overwhelmed by the sheer scale of growth.” Urgent action is needed now to avoid significant costs of inaction, both in economic and human terms (OECD, 2012). A mix of policies is needed because the different environmental issues are complex and closely linked. Policies must be carefully designed to account for these cross-cutting environmental functions and their wider economic and social implications (OECD, 2012).

Economies have the capacity to adjust to different conditions via different policy tools. To keep an economy near its full employment potential, monetary policy can be used as it aims to preserve the value of money over time. For example, a person with no debt and no savings will feel little or no impact from interest rate changes. On the fiscal front, “automatic stabilisers” will take more taxes from regions that are doing well (assuming income rises relatively quickly) and transfer it to areas doing less well, in the form of welfare payments. There is a similarity between the effects of the two policies. A person with no debt and savings will be indifferent to interest rate changes, just as a person with low income will be indifferent to tax rate changes. Taxes have a dark side (death of politics) with socially regressive effects. The 1993 SNA describes taxes as unrequited because the government provides nothing in return to the individual unit making the payment (United Nations et al., 1993). Thus, there must be compensation in the form of reduced income tax or added social security; the latter benefit is something that, arguably, would elicit appreciation from the poorer segments of the population. The poor tend to benefit less from tax reductions because they do not have significant incomes to be taxed. A direct subsidy offered to the poor is usually better than a tax reduction. However, if the economy faces a problem of a different nature, for example, excessive environmental degradation caused by market failure, an integration of environmental taxes, or “green” tax reform (Gago and Labandeira, 2000), would be a much more efficient response.

The 2008 SNA defined an environmental tax as one whose tax base is a physical unit that has a proven specific negative impact on the environment (United Nations et al., 2008). There are four types of environmental taxes: energy, transport, pollution, and resource. Hecht (2005) defined environmental taxes as “green taxes” intended to discourage the use of polluting products by raising their prices. The revenue from taxes can cut budget deficits while meeting environmental objectives. However, “green taxes” may be detrimental to economic growth (Myles, 2000). Hence, the tax structure should be more critical than the tax level. The optimal environmental tax would internalise the externality and would restore the efficiency of the market mechanism (Sandmo, 2003).

Environmental taxes can also refer to those revenues dedicated to environmental expenditures. Such expenditures are defensive as they are aimed at preventing pollution and managing natural resources. But environmental taxes alone cannot be accountable for the maintenance of the environment. Effectiveness of the policy would also have to depend on the holistic nature of the wider economic society. The revenue from “green taxes” can be recycled to allow other forms of taxes, for example, income tax, to be reduced towards a “green income”. This was evident in the case of Sweden (Sterner, 1994), where a 1991 tax reform changed the tax mix. Direct taxes on individuals and firms were reduced, without incurring additional public deficit, when a value-added tax on energy consumption and environmental taxes on carbon dioxide (CO_2) and sulphur dioxide (SO_2) emissions were introduced. Similarly, Collier (2010) advocates a carbon tax because it allows taxation on other economic activity to be reduced, and would be better than a heavily compromised emissions trading scheme (Garnaut, 2008).

There can also be tax relief and other "green" investment incentives for businesses and consumers alike. These can help prioritise "green" jobs over other jobs. Some "grand-fathering[13]" will be required for businesses that may be disadvantaged by these introductions in the early stages of implementation. These initiatives provide positive effects on employment and the environment – the "double dividend[14]". Thus, "green taxes" can shift the economy towards a green equilibrium, especially in periods of economic crisis or public debt. But this may not be the case, as income might still play a crucial role (Schumacher, 2009). Although there are obstacles to environmental fiscal reforms, these obstacles can be overcome (Ekins and Speck, 2000). After all, the environmental benefits may not be economically harmful. The overriding concern from a policy viewpoint is whether the "double dividend" from environmental taxes can raise revenue without limiting economic growth (Myles, 2000). A study by Sandmo (2003) concluded that taxes raised revenues, but it was inconclusive regarding their contribution to economic growth.

Daly (2007) suggested raising the price of natural capital through a public policy of taxation. In line with macroeconomic objectives, taxing income should be avoided because income and employment are importantly crucial, being the key components of an economy. Taxes should be applied increasingly to pollution because it is what an economy can do without. Daly (1996) proposed that labour and income should be taxed less and resource throughput taxed more. This is in

[13] "Grand-fathering" cannot go on forever as it does not help to improve existing debt position for an economy.

[14] "Double dividend" refers to taxes levied on goods causing environmental damage, which have the twin benefits of reducing the environmental damage and raising revenue (Goulder, 1995). In addition, Kolstad (2000) suggests that such taxes would not only reduce pollution but would also reduce the distortions associated with existing taxes. Note that the findings on "double dividend" are still not conclusive as per OECD (2001, 2006).

line with Sedjo's (2010) response to [Nordhaus (2010)], which stated that taxes should be imposed according to emissions instead of at the source. This provides an incentive to develop technologies that better utilise fossil fuels and, at the same time, control the release of emissions into the environment (Sedjo, 2010). The regressive effects of taxes can be offset by spending the tax revenues progressively, with emphasis on spending on industries that need it the most, an action that might help soften the regressive tax effects as well as satisfy the distributive concerns while raising public revenue. There are no doubts about what taxes can achieve – after all, taxes have been used in most economies for centuries.

According to the OECD report on Taxation, Innovation and the Environment (October 2010), OECD governments are increasingly using environmentally related taxes because they are typically one of the most effective policy tools available (OECD, 2010). Green growth policies can stimulate economic growth (and create jobs) while preventing environmental degradation, biodiversity loss and unsustainable natural resource use. Environmental policy tools should strive to ensure environmental improvement is not delayed as well as to stimulate innovation and development of clean technologies for the future. It is important that the government takes the lead in such innovations as market forces alone are inadequate to provide the right signals. Emissions will continue because there is no price attached to polluting.

To minimise the tax commitment, environmentally related taxation provides an opportunity for innovation to stimulate development and diffusion of new technologies and practices. A study conducted by the OECD found that the higher the tax rate, the more significant the incentives for innovation. Thus, innovation can be encouraged by increasing or decreasing the level of taxes. It was also found that when used with environmental policy instruments to protect environmental quality and public good provisions, taxes can complement each other (OECD, 2010). See earlier studies by Bovenberg and Goulder (1996) and Parry and Bento (2000) in which the findings are less favourable when such interactions are ignored. However, for such complements to occur, pollution must be adequately priced via taxation. Optimal policies (as suggested by the OECD) should:

i. Address the oversupply of environmental damage in society, and
ii. Place a significance on taxing environmentally harmful activities to address the environmental damage

In addition, such market-based instruments can also generate much-needed fiscal revenues (OECD, 2012).

Consider the following scenario to illustrate the two points cited above: A pollutant-emitting plant is located not far from a vineyard. The pollutant is polluting the water catchment that the vineyard uses. A moderate approach would encourage the plant to relocate through the enticement of a tax concession or rebate for the first production year, followed by a progressive tax structure from the second year onwards. The plant can choose to pass on the tax savings as lower product pricing to the end consumer. Lower taxes can also encourage product innovation, which can stimulate greater investment to increase AD in the short run and an economy’s capacity in the long run. Alternatively, the plant can choose to reinvest the tax money in initiatives that would contribute to maintaining the environment. With the departure of the plant, the clean water catchment would be more conducive to winemaking. The environment can be maintained and provides an opportunity for the plant to explore green innovative methods of production in another location. Assume now that the plant in question is old. A more complicated approach would be to increase taxes as opposed to tax concessions. This would either push the plant to be efficient in its methods of production or force it out of production completely.

It has been suggested that taxes serve as a bridging mechanism between doing nothing and preparing for a time when the economy is required to reach certain emission reduction targets (Parkinson, 2010). To be sure, taxes are not simply bridging mechanisms. Instead, they are an immediate response to slowing the rate at which natural resources are being utilised in an economy. Natural resources are being utilised faster than they are being replaced. This is illustrated by developed economies operating at close to or beyond their capacities. In addition, environmentally related taxes can help maintain the degraded environment by reinvestment of the tax revenues. The tax revenues can be reinvested through a portfolio of KN investments. A similar portfolio approach has been implemented in California for a mix of portfolio in energy generation (Dyer, 2010). For example, 33 per cent of the total power generation capacity must be sourced from renewable energy by 2020. According to Project Catalyst (2010), this is perhaps driven by the authorities' interest in economic development, energy security and climate.

Effective policy will be critical to shift investment towards "green growth" (Project Catalyst, 2010). This means that policy choices must be coupled with the appropriate financial support. The literature review on policy intervention suggests that such reinvestment in KN can be financed by taxes. However, there are certainly other forms of intervention; such as lifestyle changes through income and wages policies. Such policies can be complemented with fiscal intervention.

4. CONCLUSION

This chapter focused on the literature review of EM. Environmental accounting failed to formally account for KN in National Income Accounting, thus setting the basis for the conceptual / theoretical analyses on EM with due recognition being given to KN. The discussion on applied policy analyses showed how the internalisation of KN had been used – albeit recommendations for further enhancements. Recommendations for the development of a robust advanced macroeconomic modelling need to be considered in order for sustainable policies to be formulated. The next chapter will provide recommendations for the proposed EM framework and a presentation of a worked model.

Chapter Three – Introductory Environmental-Macroeconomics Framework

1. INTRODUCTION

This chapter will start with an initial introductory environmental-macroeconomics (EM) framework. This framework has been refereed and published (Tan and Thampapillai, 2011) but further enhancements can be made to render it more robust, and the chapter will conclude as to what these enhancements entail.

2. EM FRAMEWORK – BACKGROUND

The introductory framework is based on Keynesian premises, and similar premises were used by Thampapillai and Uhlin (1997). Further implications of the analysis by Thampapillai and Uhlin (1997) pertain to the relationship between macroeconomic evidence and microeconomic imperfections. Microeconomics ensures optimality, but when aggregated with macroeconomics, it is the trade-off between macroeconomic problems of unemployment and inflation that would greatly arouse the interest of policy makers. For example, adjusting wages can fix labour market imperfections relative to unemployment and contribute to sustainable macroeconomic equilibrium. However, the trade-off for lower unemployment is higher inflation. A similar argument can be applied to the resource markets. This allows for proper pricing of resources, by internalising environmental externalities and adopting "shadow prices", which is central to a macroeconomic equilibrium that recognises the environment. A common belief is that by attaching a price to the environmental resource, environmental damage can be "bought", and the cost of the damage is embedded in the purchase. This belief is not the case as the accumulated degradation made to the environment remains in the ecosystem.

Although proper pricing can be assigned (as in the case of pollution price tags) and internalised, prices derived are based on each economy's efforts towards clean energy competitiveness. Different economies use different methods and justifications for price setting, and this does not allow for a fair comparison to be made across the economies. It was acknowledged in the report by The Climate Institute that there are challenges in assessing direct and indirect pricing of climate change policies (The Climate Institute, 2010). It is reassuring that there are several proxies in place, but of concern is whether the proxy provides a comprehensive representation of environmental degradation.

There are several proxies to environmental degradation. Thampapillai, Wanden, Larsson, and Uhlin (1998) used energy consumption expenditures as a proxy to environmental degradation. This was tested in two nations, Sweden and the US. This analysis proposed formulating policies pertaining to environmentally sustainable income and employment. The policies included improving environmental capital efficiency, real wages, and environmental capital investments. A similar comparison of the two nations was tested a decade later by Thampapillai (2007) to emphasise the scarcity of KN. The proxy for KN is confined to the airshed of an economy that gets utilised in the process of economic growth. Despite improvements in the rate of KN utilisation (being used more efficiently), KN still remains scarce in the two countries studied. Thus, it is possible to determine the importance of KN in terms of its magnitude and price. Moreover, although technological advances coincide with resource scarcity, mitigation of resource scarcity should still be a priority. Another way to reduce resource scarcity is to restore environmental sinks by reducing cumulative pollution loads, instead of only the marginal loads (Thampapillai, 2008).

For example, in the case of Canada, resistance to further commodification[15] of nature is notable as her history has been characterized by the exploitation of its natural resources, on which much of the economy still depends (Hessing, Howlett and Summerville, 2005). Hessing, Howlett and Summerville (2005) put it down to three inter-related Ss – sources (supply of materials and services), sinks (disposals), and services (how nature has transformed nature in ways that deprive human beings of essential services like clean air and water). One of the effects of the overuse of assimilative capacity is to diminish the supply of services that nature provides and on which humans depend.

Aside from energy consumption expenditures and the airshed of an economy, there are other proxies to environmental degradation. For example, loss of forest cover, loss of marine biodiversity, rising sea levels, cyclones and floods. Loss of forest cover can lead to landslides and loss of biodiversity. Rising sea levels suggest higher sea surface temperatures; this is a pre-condition for the formation of tropical cyclones (Harvey, 2010). High sea-surface temperatures and large amounts of moist air over the Indian Ocean may have triggered the Pakistani floods and the heat wave in Russia (Ananthaswamy, 2010). Policies, such as reducing emissions from deforestation and degradation (REDD), have called for better land use planning, for example, forestry, ranching, vineyards, and wetland restoration, and serve to maintain KN as well as create jobs. However, debates over procedural hurdles mean a lack of progress in the REDD-plus Partnership (which includes forest conservation, sustainable management of forests and carbon stock enhancement) (Haverkamp, 2010; Kant, 2010).

---

[15] Commodification is one of the processes by which the economy influences society and nature. It refers to the conversion of something outside the economy into a commodity for purchase and sale (Hessing, et al., 2005)

It is apparent that the interest lies in the ease of internalising the degradation into the macroeconomic framework. Because there is a range of proxies for environmental degradation, a feasible solution might be one with a portfolio of solutions for maintaining each proxy, for example, carbon reductions, energy consumption, airshed quality, marine biodiversity, reforestation, and wetland restoration. However, one needs to be aware that evaluating the causes of environmental degradation is partly contingent upon the manner in which questions are framed, leading to quite different interpretations of the findings (Rathzel and Uzzell, 2009).

The above review clearly identifies a need for advanced macroeconomic modelling and analyses that explicitly incorporate KN, such that meaningful and efficient policies can be formulated.

According to Hartwick (1997), un-remedied degradation that carries forward to a future period is environmental debt. Thus, it is not only about internalising KN but also about reducing and maintaining the KN stock – to reduce the environmental debt. As pollution loads accumulate and degrade the sink capacity, there is an urgent need to invest in the maintenance of KN. Monetary capital is required to finance this investment. To do this, policy makers have a range of tools they can choose from, including monetary, fiscal, income and exchange rate policies. These policies have a stabilising effect by influencing AD, economic activity, income distribution, and resource allocation. Of interest is fiscal policy – government expenditures financed by tax revenues. Fiscal policy is deemed appropriate because the taxes collected can finance the reinvestment of KN and thereby maintain the economy for sustainability.

There are two issues to contemplate. Firstly, how much marginal tax can the economy tolerate, as one must not forget that a policy of tax increases can be a potentially fatal decision for politicians. Thampapillai, Wu and Tan (2010) suggested that additional taxes need to be reinvested within the confines of fiscal balance. Secondly, environmental regulations limit the options for environmental innovation: environmental regulation is said to reduce the time available to seek an optimal solution (Rothwell and Zegveld, 1981; Rothwell, 1992), decrease the freedom to innovate, and increase bureaucracy (Braun and Wield, 1994). Thus, an ideal context for KN reinvestment requires the combination of market structure (competition), incentives for innovation, and penalties for regulatory infringement. More importantly, it should not result in an obsession with returns and vested interests, as per the new investment measure proposed by Repetto and Dias (2006).

When it comes to the reinvestment of tax revenue through a portfolio of KN investments, there are two key questions to answer. Firstly, how should the budget be allocated for different KN investments? Secondly, how should the low hanging fruit be identified? In other words, which KN investment takes priority? There may not necessarily be a rule or a straightforward answer because the solution is dependent on the context. But if there were no reinvestments, there would be no positive impacts on the environment. Assume an economy relies on its natural resource for economic growth; this resource is an endowment to the society. Thus, it is only fair that the resource be maintained for future generations, to ensure avoidance of a potential resource curse (Humphreys, Sachs, and Stiglitz, 2007). In this scenario, taxing and reinvesting in the natural resource industry must take precedence over other sectors.

3. THE INTRODUCTORY EM FRAMEWORK

Most economics textbooks do not account for natural resources. For those authors who did acknowledge natural resources, they had failed to consider natural resources in the production function. Such negligence may have resulted in an exaggeration of an economy's capacity, or in severe implications for employment and inflation as well as economic growth, for these are the goals of macroeconomics.

The literature on environmental accounting suggests that identifying continuous steady growth as the steady state is not sustainable. The unsustainability of the steady state is attributed to the different methods of measuring KN and the failure to account for depreciation when accounting for the environment. The literature that appreciates the concepts of the EM framework proposes to measure KN depreciation and internalise it within macroeconomic frameworks. The recognition afforded to KN indicates that the current level of KN must be maintained and the degraded KN restored.

Following the standard macroeconomic model (Chapter One) and the literature review (Chapter Two), two key challenges to the standard framework are observed.

I. Firstly, the standard framework may not accommodate continuous growth without the internalisation and the allowance for the depreciation of KN. This will result in macroeconomic policies to be incorrectly applied as the policy domain which excludes KN may be misrepresented.

II. Secondly, KN is ignored because there is no universally agreed-upon method for measuring KN.

If these challenges are addressed, the framework can be revised to the EM framework. In a simple Keynesian framework, KN can be afforded a similar measurement to KM, analogous to that of an income-bearing asset. That is, KN will undergo the same depreciation treatment as KM to account for the loss in its ability to generate future income. The following analysis aims to account for the above discussions.

The analysis is limited to a simplified Keynesian framework where aggregate income (Y) is determined by aggregate expenditure[16]. Aggregate expenditure is confined to gross domestic product (GDP) and assume (for reasons of simplicity) that all components of GDP barring consumption (C) and investment (I) are fixed. Hence the sum of government expenditure (G) and net exports (NX) is assumed to be contained in a constant (denoted by Φ) during a given time period. The methodology employed relies on the analytics of point estimates. That is given assumed functional definitions for the components of GDP, the coefficients in these definitions are elicited as point estimates from the data.

[16] The framework and empirical illustration was published in a refereed publication as "Assessment of Fiscal Intervention Measures in China: Perspectives from Environmental Macroeconomics", (with Thampapillai, D.J.) *Critical Issues in Environmental Taxation, Volume IX*, Environmental Taxation in China and Asia-Pacific – Achieving Environmental Sustainability through Fiscal Policy, Edward Elgar, pp. 55 – 65, November 2011

The assumed functional definitions of C and I are as follows:

$$C = \alpha + \beta Y\ (1 - \tau) \tag{3.1}$$

$$I = \bar{I} + \delta Y \tag{3.2}$$

In (3.1) α, β and τ represent respectively autonomous consumption, the marginal propensity to consume and the rate of taxation. By assuming $\alpha = 0$, the point estimate values of β is elicited as:

$$\left(\frac{C}{(Y - T)}\right) \tag{3.3}$$

In (3.2) $\bar{I}$ represents fixed investment which is also contained in Φ such that ($\Phi = \bar{I}$ + G + NX) and point estimate values of δ (propensity to invest) are defined as:

$$\left(\frac{I - \bar{I}}{Y}\right) \tag{3.4}$$

A simple definition for the equilibrating value of Y within standard framework which is based on ($Y \equiv GDP$) is given by:

$$Y^* = \frac{\Phi}{[1 - \beta(1 - \tau) - \delta]} \tag{3.5}$$

For the sustainability framework the equilibrium for income determination is redefined as ($Y \equiv GDP - D_{KN}$). If the analysis of KN is confined to the depreciation of the airshed in terms of air pollution and the depreciation of agricultural soils in terms of utilizing chemicals including artificial fertilizers. Hence D_{KN} is estimated as the sum of the costs of abating air pollution and applying chemicals and fertilizers on agricultural soils. Both air pollution and chemicals / fertilizer application data were drawn from the latest issues of the World Development Indicators (World Bank, 2010). The air pollution loads were all presented in CO_2 equivalents and the unit cost of abatement was equated to USD 40 per ton[17] following World Bank (2007). The cost of chemical and fertilizer usage was averaged to USD 400 per ton following United States Department of Agriculture (2010). Hence the definition of γ could be differentiated in terms of air pollution (AP) and soil degradation (SD) as follows:

$$\gamma_t = \gamma_t^{AP} + \gamma_t^{SD} = \frac{D_{KNt}^{AP}}{GDP_t} + \frac{D_{KNt}^{SD}}{GDP_t} \tag{3.6}$$

If cost of depreciation D_{KN} is denoted as a simple linear proportion γ of GDP then the equilibrating value of Y will be:

$$Y^{**} = \frac{\Phi(1-\gamma)}{\{1-(1-\gamma)[\beta(1-\tau)+\delta]\}} \tag{3.7}$$

The level of extra taxation ($\Delta\tau$) that is required in the standard framework for synonymity with the sustainability framework can be determined by adding $\Delta\tau$ to τ in the denominator of (3.3) and then resolving for $\Delta\tau$ by equating the amended expression of (3.3) with (3.5). Thus it follows that:

$$\Delta\tau = \frac{\gamma}{\beta(1-\gamma)} \tag{3.8}$$

[17] The abatement of these loads was valued at USD 40 per ton of CO_2 equivalent (Year 2000 price).

Consider next a context wherein an economy levies a sequence of extra taxes each year over a period of T years (1, …, T), namely ($\Delta\tau_1$, $\Delta\tau_2$, ..., $\Delta\tau_T$). The contention is that when each $\Delta\tau_i$ is returned as KN investments, then D_{KN} and γ in some subsequent time period say (i+t), would begin to decline permitting the economy to expand and become both resilient as well as sustainable. For this analysis, T = 1, 2, 3, that is extra taxes are considered for the first three years. The empirical tables are presented in Appendix 3.1 with some key findings presented in the next section.

4. A SIMPLE ILLUSTRATION – CHINA

Figure 3.1 displays the comparison of the incomes determined from the standard framework income (Y^*), and the sustainable (EM) framework income (Y^{**}). The actual GDP income (Y_A) observed during the first six years (2004 to 2009) are also included in the comparison.

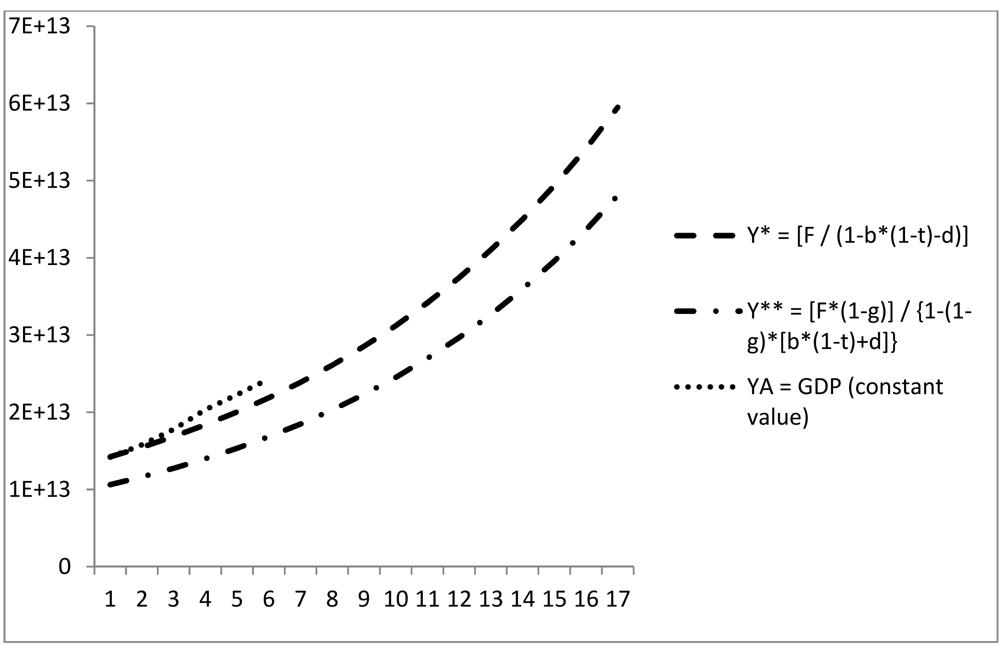


Figure 3.1: Standard Framework (Y^*) versus Sustainable Framework (Y^{**}) versus Actual Income (Y_A)

The actual income, Y_A = GDP is marginally in excess of Y^* in the first three years from 2004 to 2006. This excess becomes more pronounced in the next three years from 2007 to 2009. An explanation may be that the fiscal stimulus offered by the Chinese government to avert the adverse effects of the global financial crisis (GFC) could have intensified the GDP. But such actions were perhaps unwarranted owing to the excess of Y_A over Y^*. An observation of significant importance is the clear divergence between the paths of Y^* and Y^{**}. This confirms China's income (Y^*) from the standard framework is unsustainable in this projected time path. The clear divergence between Y^* and Y^{**} in Figure 3.1 is further reinforced by the increasing size of $\Delta\tau$. As shown from Figure 3.2 below, the magnitude of additional taxes needed for sustainability (equations above) starts from 44 per cent in 2004 and extends progressively to 56 per cent in 2020 (based on the trends developed).

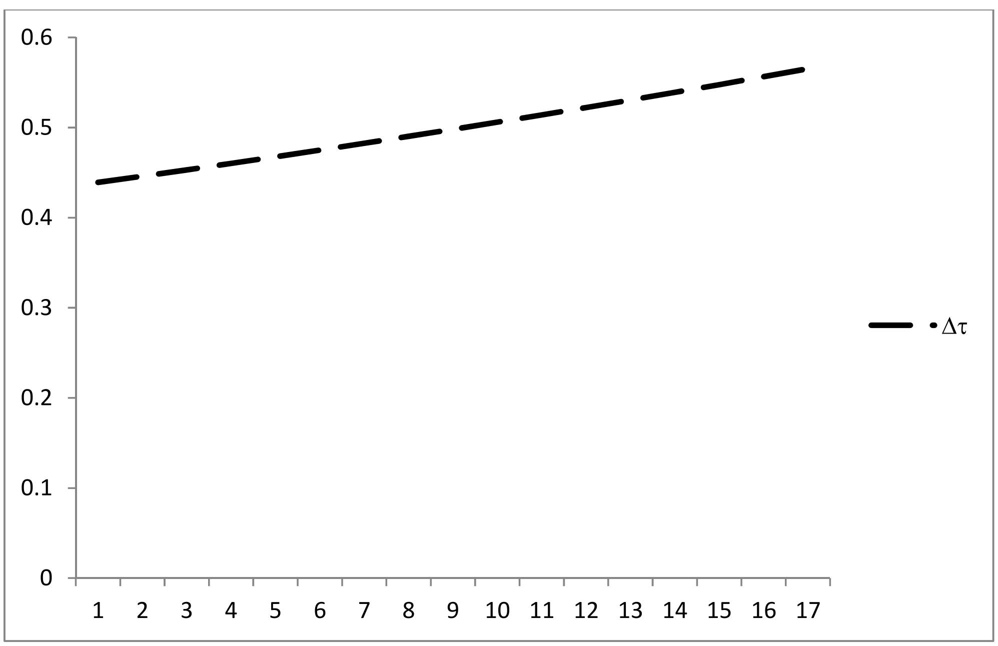


Figure 3.2: Magnitude of Extra Taxes ($\Delta\tau$)

The effects of extra taxation and return of these taxes as KN investments are considered next. As indicated above the extra taxation ($\Delta\tau$) is considered at two levels, namely 2 per cent and 5 per cent. Two types of KN investments are considered, namely reforestation (RF) and the transformation of existing patterns of farming into organic agriculture (OA). Investments in RF and OA are expected to render γ_t^{AP} and γ_t^{SD} to decrease respectively following a lag period of six years. And it is assumed that the per hectare cost of RF and OA are the same because both of these involve income losses in terms of opportunity costs from agriculture. Hence the extent of land area that could be allocated for either RF or OA can be estimated by dividing $\Delta\tau$ by the per hectare cost of investment. Given the equality of the opportunity cost of KN investments, $\Delta\tau$ is assumed to be divided equally between RF and OA (in any given year). The figures below compare standard income, Y^* and sustainable income, $Y^{**}(I)$ which incorporates reinvesting taxes towards KN. Figure 3.3A deals with $\Delta\tau = 2$ per cent and figure 3.3B deals with $\Delta\tau = 5$ per cent.

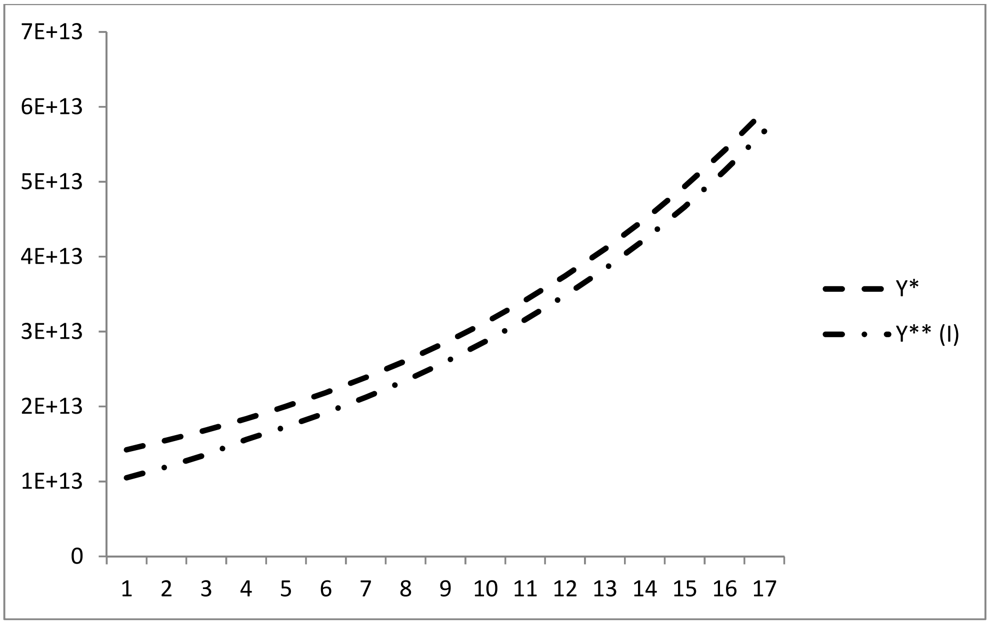


Figure 3.3A: Standard Framework (Y^*) versus Sustainable Framework (Y^{**}) with 2 per cent Extra Taxes Reinvested in Environmental Capital

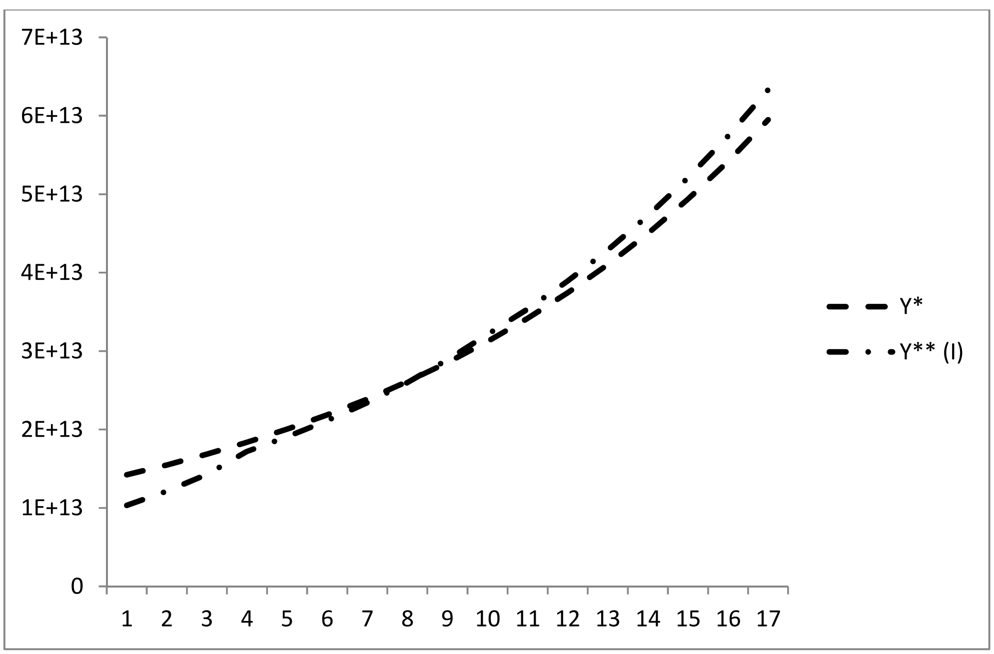


Figure 3.3B: Standard Framework (Y^*) versus Sustainable Framework (Y^{**}) with 5 per cent Extra Taxes Reinvested in Environmental Capital

In this context (Figure 3.3A and 3.4B), Y^* has neither tax considerations nor reinvestment whilst $Y^{**}(I)$ has additional taxation for the first three years that leads to reinvestment. The additional taxes collected in a given year are assumed to be reinvested in the subsequent year. Such reinvestment of the taxes has allowed:

a. for $Y^* > Y^{**}(I)$, but with strong possibility of convergence at the 2 per cent extra taxation level; and
b. for $Y^{**}(I)$ to exceed Y^* after eight years at the 5 per cent extra taxation level

However, if the reinvestment of the extra taxes is not included in the accounting process then the path of Y^{**} remains below that of Y^* as in Figure 3.4A and 3.4B.

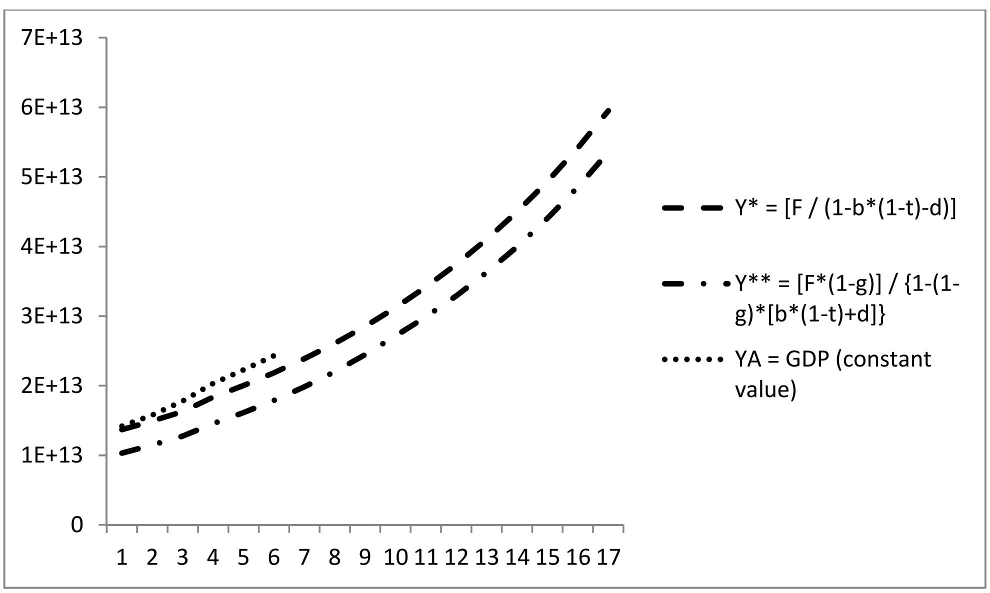


Figure 3.4A: Standard Framework (Y^*) versus Sustainable Framework (Y^{**}) with 2 per cent Extra Taxes but No Reinvestment versus Actual Income (Y_A)

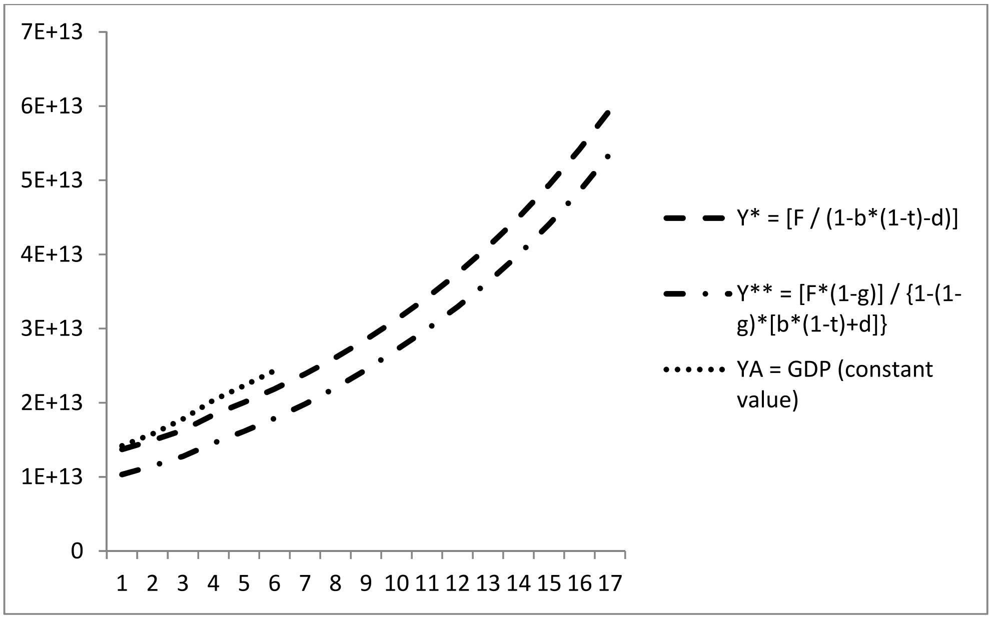


Figure 3.4B: Standard Framework (Y^*) versus Sustainable Framework (Y^{**}) with 5 per cent Extra Taxes but No Reinvestment versus Actual Income (Y_A)

The divergence though between Y^* and Y^{**} in Figure 3.4A and 3.4B is less pronounced than that observed in Figure 3.1 where extra taxation is not considered. It is observed from the figures that there is a marginal narrowing of the divergence when extra tax taxes were imposed. This is primarily due to the reduction in γ. The reinvestment of taxes goes towards reducing environmental degradation and the buildup of KN stocks.

The analysis considered thus far highlights the importance of KN investments which could be facilitated through a system of marginal taxes. A complete analysis should involve the identification of an exhaustive portfolio of potential KN investments. As outlined by the 12th Five-Year Plan (2011-2015), China is still very dependent on coal (non-renewable) to meet her energy demand. In a move to shift her demand away from coal, there have been noticeable successes from both the non-renewable and renewable sectors. Nuclear (non-renewable) expansion is very much on the energy development agenda, but safety and an adequately trained workforce are two major challenges (Zhou, Rengifo, Chen, and Hinze, 2011). On the renewable[18] front, the photovoltaic industry exports more than 95 per cent of its production (Tour, Glachant, and Ménière, 2011). Besides the two actions of reforestation and organic agriculture considered above, some potential investments include: methods of biomimcry (Benyhus, 2002); closed loop systems in sanitation (Ciambrone, 1997: Graedel & Allenby, 2001; GTZ, 2006; McDonough & Braungart, 2002); exploration of renewable energy sources; and low emission bio-fuel from algae (Hartman, 2008).

Although there is no universal tax response to financial turmoil or economic difficulties (Krever, 1995), the same may not apply to environmental degradation. With the continual degradation of the environment, one possible way to maintain the sink function is to reinvest via taxes. It is possible that such financing of KN reinvestment via taxes can ride on China's ongoing tax reform program (Xu and Halkyard, 2010) and gain much needed traction against economic development. And whilst China's energy security policy is still evolving (Tsang and Kolk, 2010; Leung, 2011), this is an excellent opportunity for KN reinvestment to be considered amidst diverging goals.

The implementation of stabilizing and reinvesting policies should be carefully planned. Reinvestment should start on a small-scale using local capacity. This ensures quick implementation that could spark-off simultaneous uptake from neighboring regions with domino effects across the wider region. Success of fiscal intervention

[18] Renewable resources does not equate to "green" resources. And as Moriarty and Honnery (2011) suggest, there is an optimum level of renewable energy use as cost will become a factor.

will encourage private investors to contribute towards the development of environmentally sustainable solutions.

The introductory framework and methodology presented above in Sections 3. and 4. were published in a book chapter by Tan and Thampapillai (2011). However, there are known limitations to this analysis.

i. The ideal analysis would be to evaluate the policy path that should have been taken as opposed to what had been taken. The illustration for China was based on Aggregate-Demand (AD) as there were no substantial time-series data for China to run alternative time-series. The data for China was available only for years 2004 to 2009

ii. The forecasts assumed that the economy can continue to grow indefinitely. Economies cannot grow indefinitely as a steady state will be reached. Macroeconomic policies may be wrongly applied because the steady state may be incorrectly represented without internalisation of and depreciation allowance for KN

iii. The forecasts made for years 2010 to 2020 helped with explaining the results achieved from the reinvestment of taxes towards KN. But there are other policy options besides taxes towards the maintenance of KN

iv. KN was not properly derived and measured – it was based on a proxy costing. Besides, the cost of CO_2 emissions needs to be updated to USD100 to reflect a more accurate representation and in line with literature

Although the introductory framework and methodology for this thesis will be similar to the illustration above, the following changes will outline the additional steps to make the model a more robust one.

i. Aggregate income (Y) will be derived based on factor utilization where it is possible to explicitly include KN as a factor of production. This allows for the derivation of steady states

ii. KN will be derived and measured with assumption that it can be measured on the same scale as manufactured capital (KM) and afforded depreciation similar to KM

iii. Furthermore, there are substantial time-series data on Y measurement. This permits the operationalisation of the methodology to selected Organisation for Economic Co-operation and Development (OECD) economies, and provides a validation of the model

These steps will be discussed in detail in Chapter 4 (Measuring KN) and Chapter 5 (Steady States) respectively.

5. CONCLUSION

There are several indicators on how the EM framework should be developed along the lines of advanced macroeconomic modelling and analyses that explicitly incorporate KN. However, there are limitations because the focus is only on AD. Hence, there is a need to:

i. Extend this to AD-AS analysis within the context of short-term policy development, and
ii. Develop a production framework that explains sustainable performance in the longer term

This chapter provided recommendations for the proposed EM framework following the illustration of an introductory EM framework – which was empirically tested. However, enhancements are required for this model before it can be operationalised for this study. Three enhancements which aim to address the key challenges of the standard framework concluded the chapter. These challenges will be undertaken in the following two chapters, beginning with the measurement of KN.

Chapter Four – Measuring Environmental Capital (KN)

1. INTRODUCTION

The measurement and accounting of environmental capital (KN) in Gross Domestic Product (GDP) has not been fully reconciled by National Income Statisticians and is still a subject of debates and differing viewpoints. Although mainstream economics has started to recognise KN, there remains no consensual approach for the measurement of KN[19]. Such complexity does not suggest that the measurement of KN, critical to the development of sustainable macroeconomic policies, is impossible. Unavoidably, however, there will be assumptions and limitations to consider.

This chapter provides the basis for measuring the role of KN in economic growth. Traditionally, the economic growth performance of an economy has been measured with reference to a 2-factor income model, which is given by Y = f (KM, L). The most widely used model is the Cobb-Douglas (C-D) factor utilisation function[20]. In this chapter, a 3-factor income model, Y = g (KM, L, KN) will be introduced as shown in Thampapillai (2012). As Daly (1997) argued, outcomes would differ if natural resources were included in the economics of production. A similar view was offered earlier by Nordhaus and Tobin (1972). To illustrate this view, Daly (1997) used a simple example of baking a cake without the ingredients. To bake a larger cake, the cook needs only to stir it faster in a larger bowl and bake it in a larger oven. The bowl and oven are the capital, and the cook is the labour. However, without the ingredients (natural resources), there will be no cake. Thus, one way to appreciate the function of KN is through the inclusion of KN in the factor income model.

[19] Wolf, M. (2012) suggests that extraordinary creativity is required to manage the current world with current frameworks.
[20] KM is manufactured capital and L is labour.

The chapter begins with a discussion of the concept of factoring KN into the factor utilisation model. This step is followed by a conceptual basis for measuring KN. A methodological framework for measuring KN follows. The empirical evidence of KN utilisation for 11 selected Organisation for Economic Co-operation and Development (OECD) economies from 1980 to 2009 is then presented. The chapter concludes with a brief discussion relating KN utilisation to income gaps (economic capacity) and employment.

2. FACTOR UTILISATION FUNCTION FROM 2-FACTORS to 3-FACTORS

The existing literature explains the distribution of national income between 2 factors, namely KM and L. A widely used model is the C-D factor utilisation function which describes the relationship between income and the inputs KM and L. Assuming that this function displays constant returns to scale ($\theta + \lambda = 1$) [Hartwick, (1978, 1991), Solow (1986), and Nordhaus (1992)], the C-D function takes the following form:

$$Y = \alpha \ KM^{\theta} \ L^{\lambda} \tag{4.1}$$

where α is the total factor productivity coefficient, θ is the share of income to capital, and λ is the share of income to labour. This is based on the assumption that the factors are paid their respective marginal products.

The coefficients θ and λ of the assumed functional forms can be estimated using point estimate data on the premise that equation (4.1) is valid. Income statements in national accounts contain an identity that allows for this estimation. This identity is:

$$Y \equiv OS + CE \tag{4.2}$$

where OS is the operating surplus, which is the sum of the payments to KM and CE is the compensation to the employees, which is the sum of the payments to L.

Therefore, it follows that:

$$\theta = [\frac{OS}{Y}] \tag{4.3}$$

$$\lambda = [\frac{CE}{Y}] \tag{4.4}$$

The contention in environmental-macroeconomics (EM) is that income, Y is not purely attributed to KM and L. KN must also be accounted for because it plays an important role in the formation of Y, similar to the above cake-making example from Daly. This relationship suggests that the contributions of KM and L in the standard factor utilisation function are overstated.

In terms of this premise, there is a need to revise the C-D factor utilisation function to the 3-factor utilisation function as follows:

$$Y = \alpha\ KM^{\theta'}\ L^{\lambda'}\ KN^{\phi} \tag{4.5}$$

where α is the total factor productivity coefficient, θ' is the share of Y to KM, λ' is the share of Y to L, and ϕ is the corresponding share of Y that accrues to KN. When KN is considered as a third factor, the same level of income would then be attributed three-ways to KM, L and KN. As a result, income in the 3-factor income model will fall below that of the 2-factor income model (Thampapillai, 2012).

The key challenge pertains to the measurement of KN. This challenge will be discussed in the next section. The following discussion on the conceptual basis for measuring KN follows Thampapillai (2012) and Thampapillai and Sinden (2012).

3. CONCEPTUAL BASIS FOR MEASURING KN

Figure 4.1 below displays both the 2-factor and 3-factor income models[21]. This figure also displays 2 horizontal scales. The first is KM, which is the accumulated stock of manufactured capital. The second is K, which is a composite measure that comprises the amount of KM accumulated and the amount of KN utilised. Thampapillai & Sinden (2012) assume that KM and KN can be measured with the same numerical scale and, hence, can be aggregated.

[21] The income definition in the 2-factor model does not make any allowance for D_{KN}. However, the definition in the 3-factor model makes an allowance for D_{KN}. With this consideration for D_{KN}, the 3-factor income model will fall below that of the 2-factor income model as indicated in Figure 4.1.

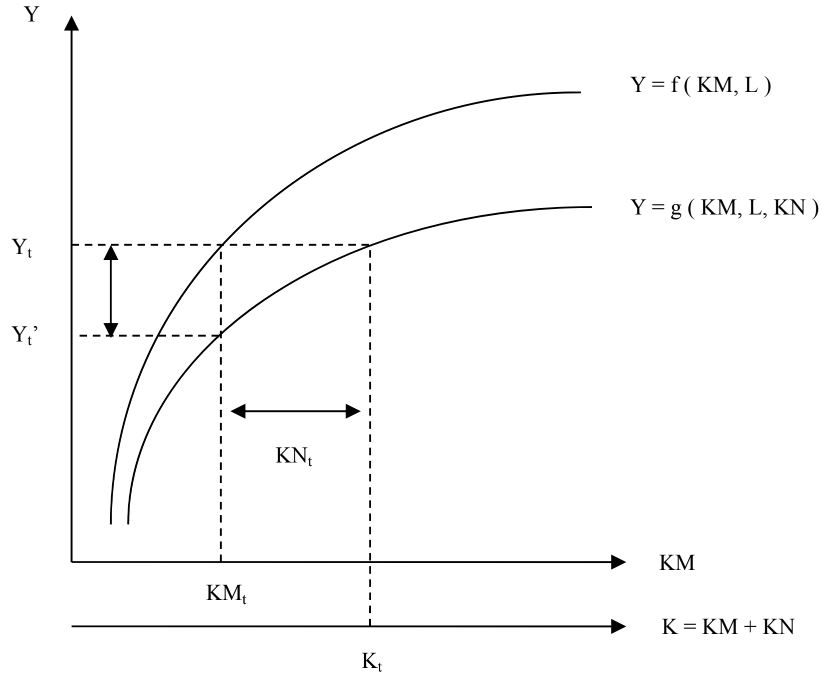


Figure 4.1: Conceptual Basis for Measuring Environmental Capital[22]

The role of KN in determining Y can be explained by comparing Y = f (KM, L) with Y = g (KM, L, KN). In the 2-factor model, the amount of KM that is required for Y_t is KM_t. However, the same level of Y_t in the 3-factor model is explained by K_t, which is larger than KM_t. This observation suggests that KN_t can be estimated as the difference ($K_t - KM_t$).

The utilisation of KN represents the depreciation in the level of existing KN stock. When Y_t is explained by the 3-factor model, the following two observations can be made:

[22] Figure 4.1 is reproduced from Figure 13-2 of Thampapillai & Sinden (2012).

i. KM_t is responsible for a lower value of Y_t' (known as sustainable Y) and not Y_t, in other words, $Y_t' < Y_t$. Hence, there is an over-estimation of the income ($Y_t - Y_t'$)

ii. At the level of Y_t, more of the aggregated capital K_t (greater than KM_t) is required to maintain this level of income

To achieve a given rate of growth, the amount of KN used towards production will increase. However, there are two challenges associated with this: one is to ensure that KN increment is constant; and two, use KN saving technology process.

To recognise D_{KN}, the income Y must be adjusted to the sustainable income, Y', by adjusting for the depreciation of the KN stock. In other words, $Y' = Y - D_{KN}$. Suppose that D_{KN} is a proportion of Y, as follows:

$$\phi = [\frac{D_{KN}}{Y}] \tag{4.6}$$

Thampapillai & Sinden (2012) assume that ϕ can be regarded as the share of Y that accrues to KN. Hence, it follows that a sustainable income, Y' would be adjusted accordingly by a factor of $(1-\phi)$ as follows:

$$Y' = \alpha' \, KM^{\theta'} L^{\lambda'} KN^{\phi} \tag{4.7}$$

where $\alpha' = (1-\phi)\,\alpha$[23].

[23] The time series point estimate is assumed valid in each year of the time series. The analysis of point estimates capture productivity changes for each year of the time series. Therefore, any change in multi-factor productivity (MFP) is made through α and α' as point estimates for each year.

Now that both Y and Y' are ascertained, an expression for KN can be obtained by dividing Y by Y' as follows[24]:

$$KN = KM^{\frac{\theta-\theta'}{\phi}} L^{\frac{\lambda-\lambda'}{\phi}} \tag{4.8}$$

4. METHODOLOGICAL FRAMEWORK FOR MEASURING KN

The following methodological framework details the steps taken to estimate KN[25]:

i. The OECD[26] economies selected for this study are Australia, Canada, France, Germany, Japan, Korea, Mexico, New Zealand, Norway, the United Kingdom and the USA. The variables selected from 1980 to 2009 are the following: Final Consumption Expenditure (C); Final Consumption Expenditure of Government (G); Gross Capital Formation (GCF); Net Balance of Goods and Services; National Income Expenditure Approach (Y); Compensation of Employees (CE); Gross Operating Surplus (OS); Net Taxes (T); Income Approach to National Accounts (IANA); GDP Deflator; and Employment (L). All of the monetary estimates are in the appropriate national currency at current prices

ii. The GDP deflator was used to convert the current value estimates to constant values. Note that the base year is 2005. To smooth any cyclical variations, the Hodrick-Prescott (HP) filter was applied to the variables C, GCF, S[27], CE, and OS

[24] The variables which constitute KN, that is capital KM (GCF), operating surplus (OS) and compensation to employees (CE) have been smoothed by the HP filter. This ensures that KN is not contaminated by business cycles.

[25] Thampapillai (2012) estimated KN by apportioning KN from KM and L. This method has limitations because it does not account for changes in ϕ, which is the share of income to KN, as a factor of income. Please refer to point vii. for a proposed response to address this limitation.

[26] The OECD database was selected because it has a full set of national income accounts with data dating to 1980.

[27] Savings (S) = GDP – C – G.

iii. The perpetual inventory method[28] was used to estimate the capital stock[29] (KM). GCF is the Investment (I) and the logarithm of GCF is computed to express the values in a more natural way. The size of the capital at the initial time period of the time series can be determined and estimated by the coefficient ω, which is defined as the ideal rate of increase for KM per annum. The initial size of the capital stock is denoted as $KM_{t=1}$ for the first year and is estimated from the GCF value. This value is defined as follows:

$$KM_{t=1} = GCF_{t=1} / (\delta+\omega) \quad (4.10)$$

where δ is the rate at which capital stock depreciates over 30 years, which is assumed to be (1/30) = 0.0333. The size of the capital stock for subsequent years can now be estimated by:

$$KM_{t+1} = KM_t + GCF_{t+1} - (\delta^* KM_t) \quad (4.11)$$

iv. The labour (L) is estimated to be the level of total labour force employed. This is obtained directly from the OECD database

v. The value of θ is estimated to be (OS / Y) as in equation (4.3) and λ is (CE / Y) as shown in equation (4.4)

vi. The variable ϕ[30] is estimated to be (D_{KN} / Y) as per equation (4.6). The value of D_{KN} is restricted to the cost of carbon dioxide (CO_2) abatement. The greenhouse gases (GHG) data are obtained from the World Development Indicators (WDI).

[28] The perpetual inventory method is used for the calculation of fixed assets when direct information is difficult to obtain (Eurostat, 1995).
[29] Note that in the absence of sensitivity analysis, the results and assumptions may not be robust.
[30] Note that in the absence of sensitivity analysis, the results and assumptions may not be robust.

The GHG are CO_2, methane (CH_4), nitrous oxide (N_2O), and other GHG [which includes hydrofluorocarbons (HFC), perfluorinated compounds (PFC), sulphur hexaflourinated compounds (PFC) and sulphur hexafluoride (SF_6)]. All of the gases are converted to tons of CO_2 equivalent, at a cost of USD100 / tonne (2005 constant prices)[31]

vii. With the introduction of ϕ (the share of income to KN), θ and λ must be revised to capture changes in the constituent of income. If the assumption that a constant return to scale holds, then $\theta' + \lambda' + \phi = 1$

Hence, θ and λ must be revised to θ' and λ'. This revision is necessary because the original variables are overstated from the inclusion of the income share from KN.

In this study, θ' and λ' were estimated using shadow pricing. The shadow price is the price of the factor of production when the market is perfect, for example when full employment is observed. Thus, the coefficients θ' and λ' can be defined as follows:

$$\theta' = (1-\phi)\left(\frac{P_{km}}{P_L + P_{KM}}\right) \tag{4.12}$$

$$\lambda' = (1-\phi)\left(\frac{P_L}{P_L + P_{KM}}\right) \tag{4.13}$$

[31] The literature has proposed for a cost of USD100 / tonne of CO_2 emissions. See Stern (2007), Ackerman, et al. (2009), Hope (2011), and Karstad (2012).

where P_{KM} is the shadow price of KM, which is estimated to be (OS / KM) and P_{Lt} is the shadow price of CE, which is estimated to be the capital equivalent price of L. The method adopted in Thampapillai (2012) is to convert CE to explain the context of unemployment. This conversion is performed by dividing CE by the labour force to estimate a wage rate that would support full employment. The revised value of CE, namely CE_{St} is then the product of the employment and the shadow wage rate, which is ($L_t^* W_{St}$). Then λ' is (CE_{St} / Y). P_{Lt} is estimated to be (CE_{St} / KM_t), which is a KM equivalent price.

viii. From equation (4.8), KN can be calculated by substituting all of the parameters that are described from steps iii. to vii. Note that these parameters are point estimates and not estimation of long-run steady state properties

5. EMPRICAL EVIDENCE OF KN FOR 11 OECD ECONOMICES FROM 1990[32] TO 2009

Based on the definition of KN given equation (4.8), the utilisation of KN was empirically measured for 11 selected OECD economies. The selected economies are Australia, Canada, France, Germany, Japan, Korea, Mexico, New Zealand, Norway, the United Kingdom, and the USA. The values for KN are presented in Table 4.1 below and are displayed in Figure 4.2.

[32] Complete data for all GHG were not available before 1990.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
AUS	108202107	25411289	12985800	11150858	17266359	29393107	31470808	30571983	47594727	57894233
CAN	127981303	61453246	51209796	52017339	64261203	91397252	84342665	101035918	122646876	146442320
FRA	92316540	77467184	33478044	14243013	6680684	16370311	12816306	7943251	13336867	9891799
GER	1392215694	1013235160	642510371	379212583	295583087	312507305	233220611	133164143	157121149	156259578
JAP	11740624005	11299915451	9855276414	5846894797	3943696951	2829099098	2326671549	2125981215	780631291	331004821
KOR	48243274288	46844356678	42295113606	36278530628	45841533293	59586569393	66339687973	56879419835	4076399011	7206088213
MEX	253630834305	271307778674	269932989311	91159814140	87283718467	25786682633	53319930575	82065704666	97831447461	137731514539
NZL	82950759	126859041	136483657	163911627	229474458	175192093	506939087	467638674	387387977	434310615
NOR	44463189	156793584	110181860	103600356	119284158	29913874	274112039	399848525	593977950	680608585
UK	159599818	81739829	41304052	24333249	29298673	47742591	63352647	83527316	117261174	102568715
USA	1859238477	1033502283	750991506	1018897624	1370129454	1767681622	1721549061	2085606543	2387404804	2647006956

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
AUS	81098958	51242209	64545566	77742171	101501023	138548986	173217127	235092605	271059660	115890459
CAN	233305598	183433035	143167319	164301093	183171564	213102020	230757057	257940982	237759724	84919409
FRA	18529057	33570376	26143308	17685220	12879069	11914380	10342587	15854160	21601945	5230245
GER	203263687	209623318	129687406	90962434	51132900	28144252	46560173	100147423	179554464	148511646
JAP	299262733	196046876	135797304	171612966	341245286	442204277	607540948	901855140	760282899	186907263
KOR	23650437282	27861795616	41344733648	31422360732	27749180507	20653139047	22488186870	26405416460	26295316795	18122341374
MEX	128858947463	132858712749	119867716941	123612171847	102509772454	120833083765	148907293096	152757358733	158001602005	93911498877
NZL	185563451	237729494	234506030	268599927	325170851	332080215	305000551	292633473	229455862	92814617
NOR	148099334	156705293	94036636	66988064	82433487	71749869	243260485	447209846	383227073	210371806
UK	106879439	152426054	100409159	111626418	118625193	109053152	61598941	56162286	50835795	5964656
USA	3208199593	2173438439	1323151116	1159015969	1470655679	1833041023	2228486632	2284012547	1285079754	211216187

Table 4.1: KN Utilisation (in Year 2005 Constant National Currency) for 11 OECD Economies from 1990 to 2009

The economies of Australia, Canada, France, Mexico, New Zealand, Norway, the United Kingdom and the USA showed a significant decline of KN utilisation in the year 2009, based on the values from Table 4.1. Germany, Japan and Korea were the three economies that did not show a significant decline of KN utilisation in the year 2009.

The historical display of KN utilisation in Figure 4.2 enables the economies to be classified into 3 groups, as follows:

i. Group 1 – Upward Trending KN utilisation

   The economies that belong to this group are Australia and Canada. Both economies display an increase in the use of KN.

ii. Group 2 – Downward Trending KN utilisation

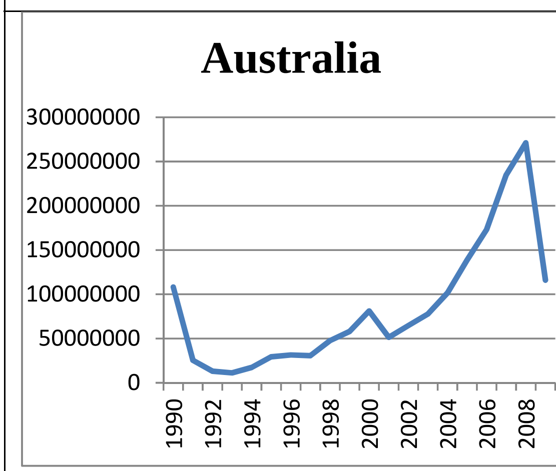
   The economies that belong to this group are France, Germany, and Japan. These economies display a decrease in the use of KN.

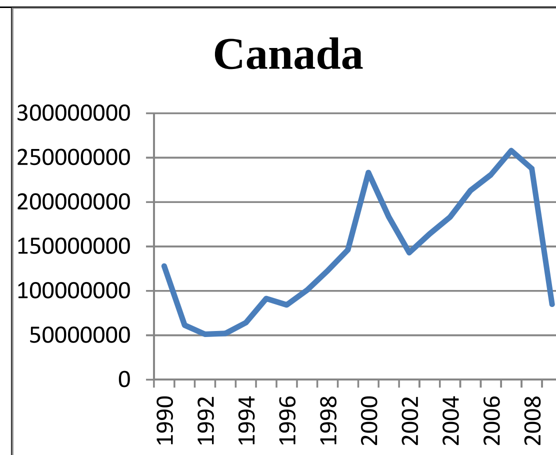
iii. Group 3 – Mixed Trends of KN utilisation

   The economies that belong to this group are Korea, New Zealand, Norway, the United Kingdom and the USA. These economies display mixed trends in the use of KN over the observed time period.

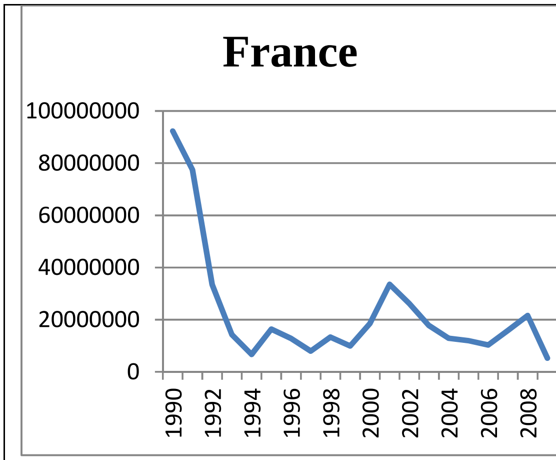
   These economies can be further sub-grouped into Group 3(A) and 3(B). The New Zealand, Norwegian, and USA economies belong to Group 3(A), where the comparisons are based on peaks before and after the year 2000. There was a peak in KN usage between 1995 to 2000 and between 2004 to 2009. In Group 3(B), changes in the utilisation of KN were observed after regional and domestic crisis. For example, Korea showed a decrease in KN usage after the Asian Financial Crisis in 1997, Mexico experienced the Peso Crisis from 1994 to 1995, and the United Kingdom was forced to withdraw from the European Exchange Rate Mechanism in 1992. Furthermore, all three economies showed a decrease in KN usage in 2009 after the 2008 global financial crisis (GFC). Note that KN utilisation is plotted on the vertical axis with time on the horizontal axis.

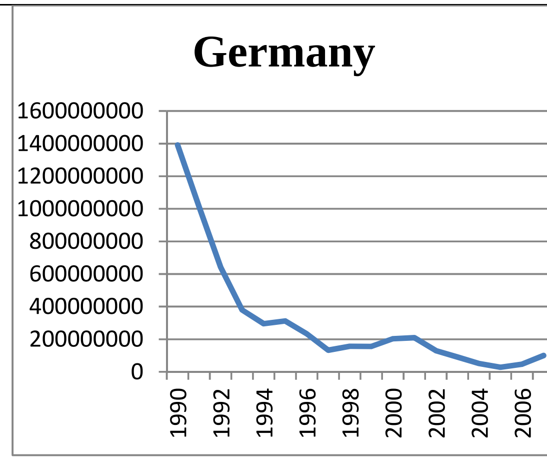
Group One – Upward Trending KN Utilisation Economies

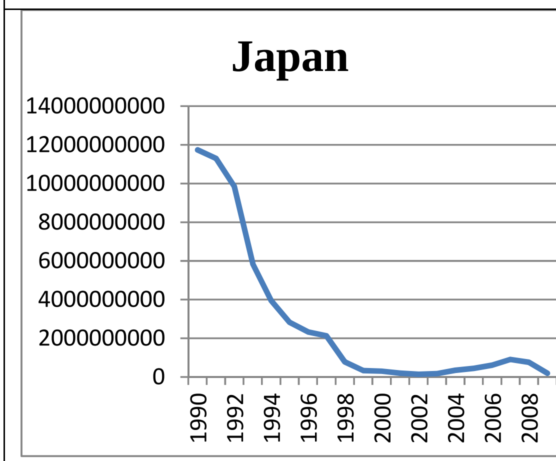




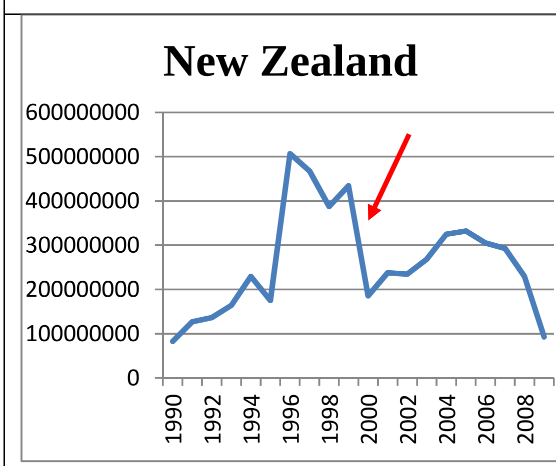
Group Two – Downward Trending KN Utilisation Economies

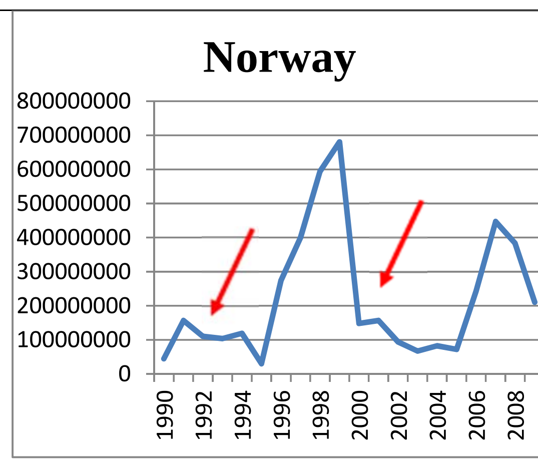






Group Three – Mixed Trends of KN Utilisation (A)

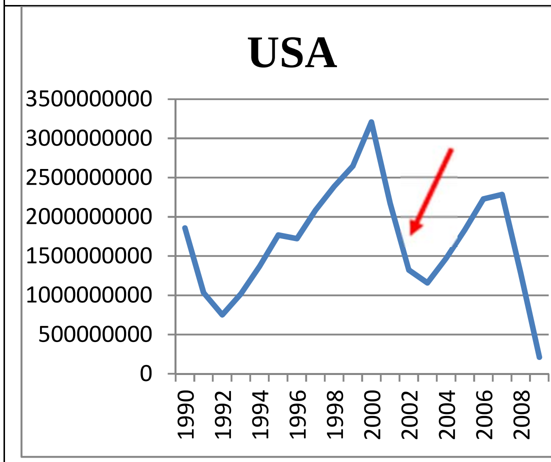
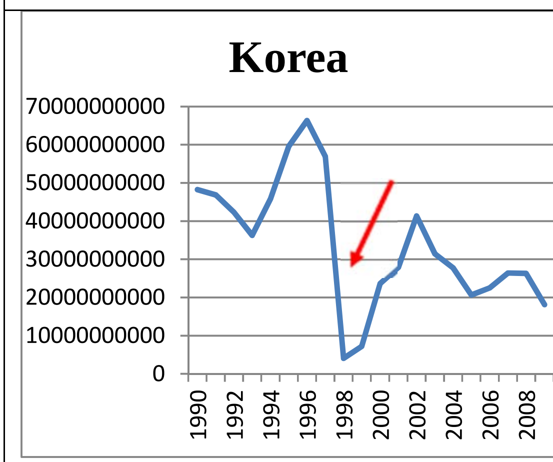
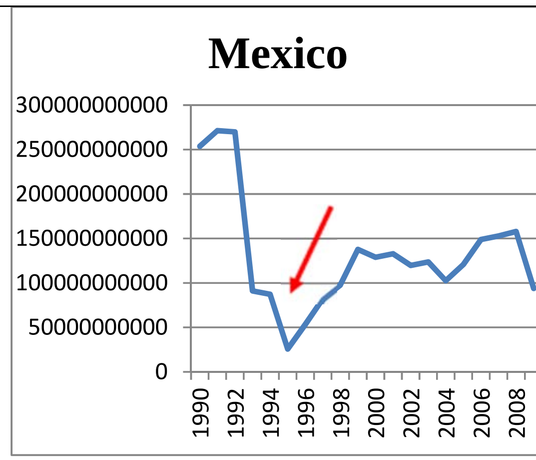




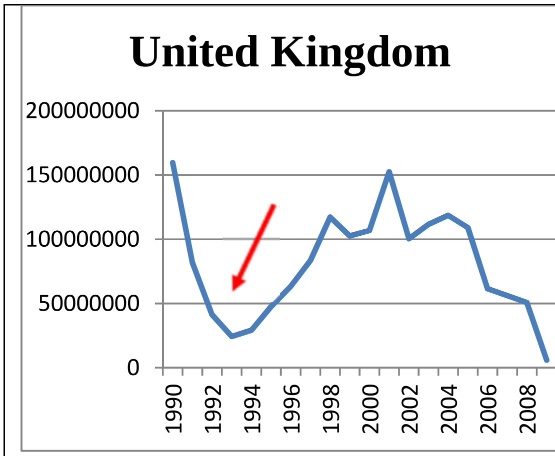
The change in the utilisation of KN coincided with the depreciation of the New Zealand dollar (NZD) against the USD in

There were two declines in the utilisation of KN for Norway. The first was from 1991 to 1994, when a new Norwegian carbon tax

<table>
<tr><td>1999-2000. This change was a reversal of an over-valued NZD. The Reserve Bank of New Zealand increased its interest rates to slow the economic activity because it was feared that the depreciating currency could lead to imported inflation[33].</td><td>was introduced to reduce greenhouse gas emissions[34].

The second was in 1999, where Norway experienced an oil crisis as investments in the oil industry were reduced, which threatened its employment levels[35].</td></tr>
<tr><td>
</td><td>The USA experienced a dip in the utilisation of KN; this dip corresponded with the dot-com bubble in 2000.</td></tr>
<tr><td colspan="2">Group Three – Mixed Trends of KN Utilisation (B)</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>With regard to the Korean economy, the utilisation of KN dipped in 1997 following the Asian Financial Crisis.</td><td>The Mexican economy experienced the Mexican Peso Crisis between 1994 and 1995[36]. There was a corresponding dip in the utilisation of KN.</td></tr>
</table>

[33] Brash, D.T. (2000), "The fall of the New Zealand dollar: why has it happened, and what does it mean?", The Reserve Bank of New Zealand, 5th October 2000
[34] Norway's petroleum history, http://olf.no/en/facts/petroleum-history/
[35] Lismoen, H. (1999), "Uncertainty hits oil sector", European Industrial Relations Observatory On-Line, 28th September 1999, http://www.eurofound.europa.eu/eiro/1999/09/feature/no9909149f.htm
[36] http://www.sjsu.edu/faculty/watkins/mexico95.htm



The United Kingdom (UK) was a member of the European Exchange Rate Mechanism (ERM) but was forced to withdraw from the ERM in 1992[37]. This action corresponded with a fall in the utilisation of KN.

The ERM aims to maintain the pound sterling within an acceptable band of the Deutschemark. This goal was central to the government's economic policy in the early 1990s and allowed the then Major government to be free from political responsibility for economic adjustment (Bonefeld and Burnham, 1996). However, it also caused the government to be detached from its economy.

Figure 4.2: KN Utilisation for 11 OECD Economies from 1990 to 2009

The general observation from Figure 4.2 is that the utilisation of KN is required for economic growth.

6. KN UTILISATION, INCOME GAP AND EMPLOYMENT

The utilisation of KN in an economy will affect the level of income that is generated. This relationship can be demonstrated with the 3-factor income model by looking at the gap between the equilibrium income and full employment income. An income gap exists between the income level at full employment and the current level of income. Hence, income gap is defined as the difference between income (Y_f) that is generated when total labour force (L_f) is employed and income (Y_t) that is generated when labour is at the current level of employment (L_t). Note that $L_t < L_f$.

[37] Bonefeld, W. and Burnham, P., "1990-1992: Britain and the politics of the European exchange rate mechanism", Capital and Class (Autumn 1996), pp. 5-38

The income gap for the 2-factor income models is estimated to be ($Y_f - Y_t$) and the income gap for the 3-factor income model is ($Y'_f - Y'_t$). Both gaps can be estimated for all of the years by making substitutions for α, θ, λ, α', θ', λ', and ϕ from point estimate data. This gap measures the capacity that is available in an economy and is measured for both of the factor income models. The effect of KN on the income model is apparent because the gap is generally smaller in the 3-factor income model relative to the 2-factor income model. Such phenomenon where the income gap in the 2-factor income model is overstated can be explained by the concept of income efficiency. For example, an economy is considered efficient when the income gap is rising with a low level of KN utilisation.

An appropriate measure to exemplify the presence of KN across both models would be:

$$[Y_f - Y_t] - [Y'_f - Y'_t]$$

If this value is positive (>0), then it is evident that in the presence of KN, the income domain has been reduced. Furthermore, if this value is positive and the trend is an increasing one, then it appears that the capacity constraint is becoming more stringent over time. The results are presented in Tables 4.2 and 4.3 as well as in Figure 4.3 which shows the time-series trends of the economies' income gaps.

Group One	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
AUS $(Y_f - Y_t) - (Y'_f - Y'_t)$	3.48E+09	5.30E+09	6.38E+09	6.60E+09	5.74E+09	4.84E+09	5.15E+09	5.19E+09	4.80E+09	4.12E+09
CAN $(Y_f - Y_t) - (Y'_f - Y'_t)$	7.49E+09	1.03E+10	1.19E+10	1.25E+10	1.09E+10	9.89E+09	1.01E+10	9.57E+09	8.42E+09	7.52E+09
Group Two										
FRA $(Y_f - Y_t) - (Y'_f - Y'_t)$	8.59E+09	8.88E+09	9.77E+09	1.13E+10	1.19E+10	1.20E+10	1.32E+10	1.31E+10	1.28E+10	1.18E+10
GER $(Y_f - Y_t) - (Y'_f - Y'_t)$	1.10E+10	1.14E+10	1.37E+10	1.67E+10	1.81E+10	1.73E+10	1.94E+10	2.17E+10	1.97E+10	1.66E+10
JAP $(Y_f - Y_t) - (Y'_f - Y'_t)$	3.78E+11	3.81E+11	4.05E+11	4.79E+11	6.00E+11	6.70E+11	7.48E+11	7.59E+11	9.35E+11	1.08E+12

Group One	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
AUS $(Y_f - Y_t) - (Y'_f - Y'_t)$	3.71E+09	4.04E+09	3.82E+09	3.53E+09	3.13E+09	2.98E+09	2.88E+09	2.63E+09	2.60E+09	3.75E+09
CAN $(Y_f - Y_t) - (Y'_f - Y'_t)$	7.07E+09	7.55E+09	8.14E+09	8.39E+09	7.90E+09	7.44E+09	6.79E+09	6.53E+09	6.74E+09	9.90E+09
Group Two										
FRA $(Y_f - Y_t) - (Y'_f - Y'_t)$	9.36E+09	8.51E+09	8.74E+09	9.72E+09	1.04E+10	1.05E+10	1.03E+10	9.00E+09	8.20E+09	1.10E+10
GER $(Y_f - Y_t) - (Y'_f - Y'_t)$	1.49E+10	1.53E+10	1.68E+10	1.87E+10	2.14E+10	2.37E+10	2.10E+10	1.64E+10	1.35E+10	1.39E+10
JAP $(Y_f - Y_t) - (Y'_f - Y'_t)$	1.09E+12	1.18E+12	1.29E+12	1.27E+12	1.11E+12	1.01E+12	9.20E+11	8.67E+11	9.10E+11	1.25E+12

Table 4.2: Gap $[Y_f-Y_t] - [Y'_f-Y'_t]$ for Group One and Group Two OECD Economies from 1990 to 2009

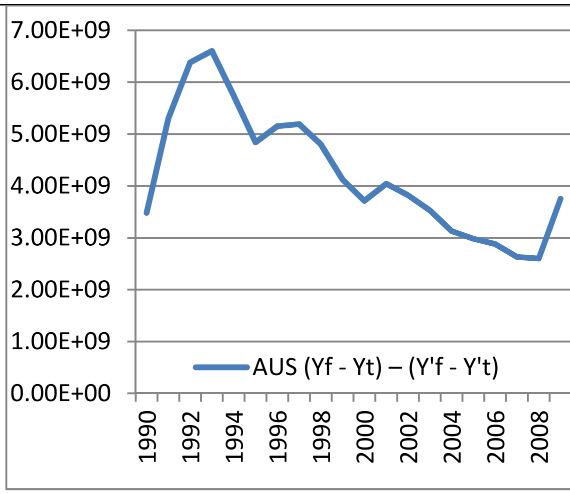
Group Three (A)	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
NZL (Y_f - Y_t) – (Y'_f - Y'_t)	8.63E+08	1.68E+09	1.69E+09	1.52E+09	1.26E+09	6.82E+08	1.09E+09	1.21E+09	1.39E+09	1.28E+09
NOR (Y_f - Y_t) – (Y'_f - Y'_t)	4.08E+09	6.19E+09	6.65E+09	6.77E+09	5.87E+09	3.70E+09	6.33E+09	5.21E+09	4.09E+09	4.25E+09
USA (Y_f - Y_t) – (Y'_f - Y'_t)	4.70E+10	5.75E+10	6.47E+10	6.14E+10	5.34E+10	5.04E+10	4.76E+10	4.40E+10	3.99E+10	3.75E+10
Group Three (B)										
KOR (Y_f - Y_t) – (Y'_f - Y'_t)	7.59E+11	8.18E+11	9.16E+11	1.17E+12	1.07E+12	9.50E+11	1.01E+12	1.37E+12	3.77E+12	3.64E+12
MEX (Y_f - Y_t) – (Y'_f - Y'_t)	9.61E+09	1.07E+10	1.16E+10	1.28E+10	1.45E+10	3.16E+10	2.43E+10	1.85E+10	1.64E+10	1.11E+10
UK (Y_f - Y_t) – (Y'_f - Y'_t)	5.13E+09	6.71E+09	7.99E+09	8.51E+09	7.68E+09	6.79E+09	6.52E+09	5.31E+09	4.48E+09	4.29E+09

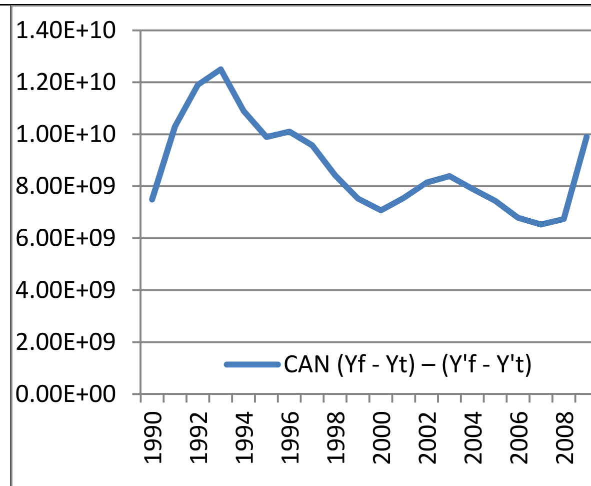
Group Three (A)	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
NZL (Y_f - Y_t) – (Y'_f - Y'_t)	7.02E+08	6.24E+08	6.09E+08	5.47E+08	4.64E+08	4.39E+08	4.55E+08	4.46E+08	5.20E+08	8.50E+08
NOR (Y_f - Y_t) – (Y'_f - Y'_t)	2.70E+09	2.81E+09	3.02E+09	3.83E+09	3.95E+09	4.06E+09	2.92E+09	1.90E+09	2.03E+09	2.55E+09
USA (Y_f - Y_t) – (Y'_f - Y'_t)	3.75E+10	4.53E+10	5.82E+10	6.10E+10	5.64E+10	5.15E+10	4.58E+10	4.65E+10	6.13E+10	1.13E+11
Group Three (B)										
KOR (Y_f - Y_t) – (Y'_f - Y'_t)	2.56E+12	2.33E+12	1.96E+12	2.17E+12	2.33E+12	2.31E+12	2.15E+12	2.13E+12	2.13E+12	2.57E+12
MEX (Y_f - Y_t) – (Y'_f - Y'_t)	1.12E+10	1.14E+10	1.30E+10	1.38E+10	1.76E+10	1.71E+10	1.53E+10	1.71E+10	1.79E+10	2.86E+10
UK (Y_f - Y_t) – (Y'_f - Y'_t)	3.79E+09	3.23E+09	3.43E+09	3.27E+09	3.11E+09	3.11E+09	3.78E+09	3.62E+09	3.60E+09	5.96E+09

Table 4.3: Gap [Y_f-Y_t] – [Y'_f-Y'_t] for Group Three OECD Economies from 1990 to 2009

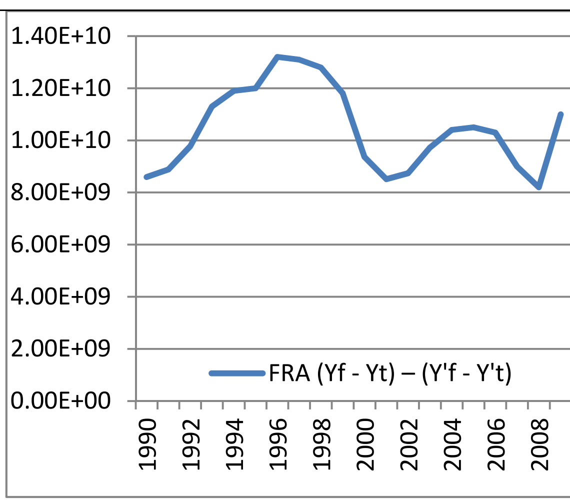
Figure 4.3 shows the trends of the economies' income gaps (on the vertical axis) against time (horizontal axis). The economies are grouped in the same category (as in Figure 4.2) to allow a comparison with the trends of KN utilisation and the income gaps of the economies.

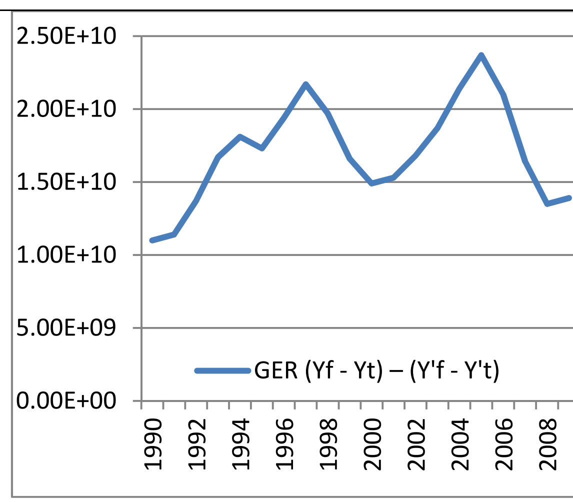
Group One – Income Gaps for Upward Trending KN Utilisation Economies

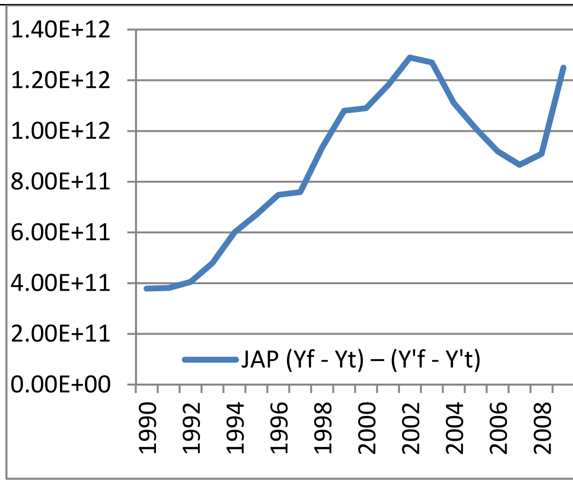




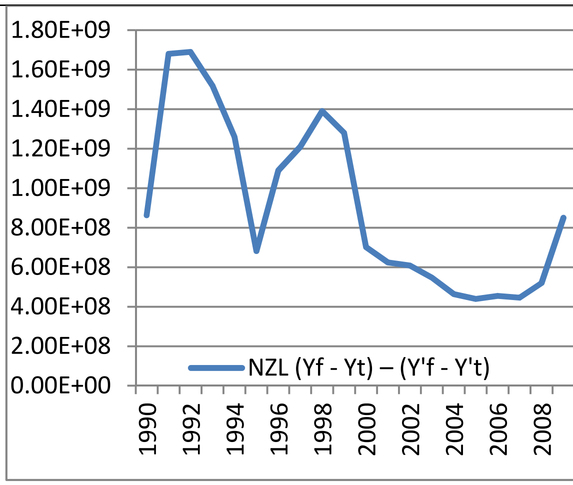
Group Two – Income Gaps for Downward Trending KN Utilisation Economies

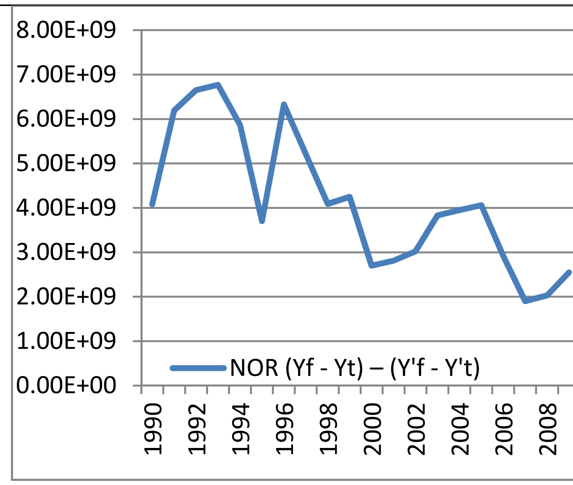


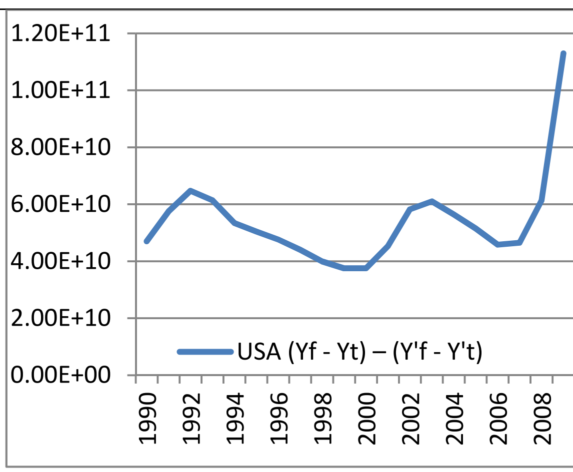




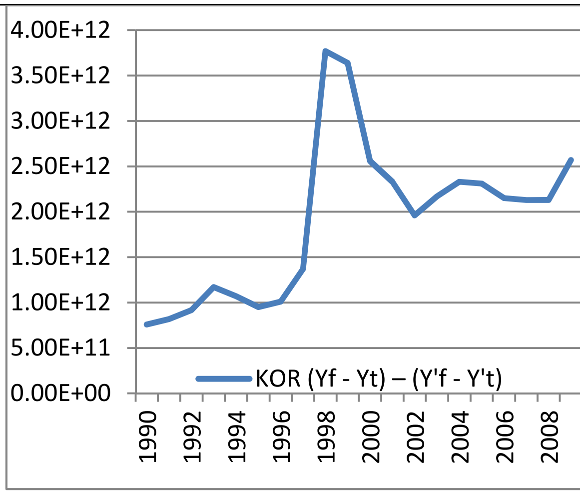
Group Three – Volatile Trends of KN Utilisation (A)

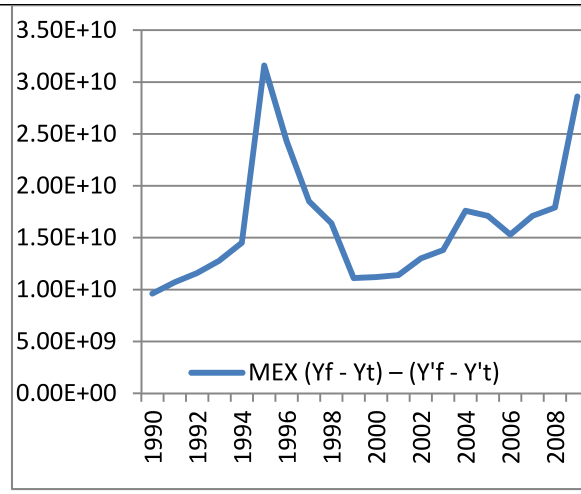






Group Three – Volatile Trends of KN Utilisation (B)





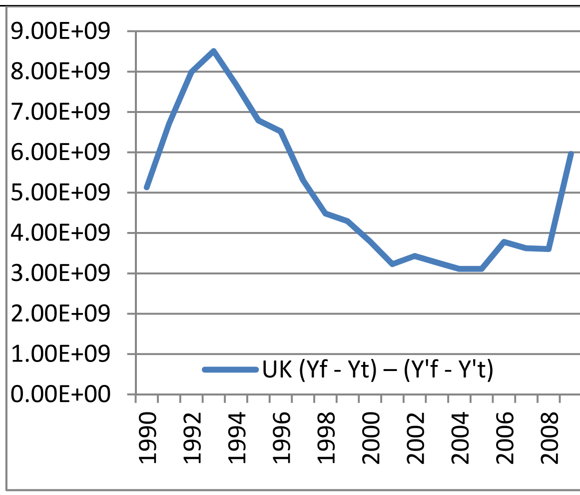


Figure 4.3: Income Gaps of the OECD Economies from 1990 to 2009

For the economies in Group One (Australia and Canada) which display upward trending KN utilisation, the income gaps displayed in Figure 4.3 have decreasing trends. These trends suggest that an increase in KN utilisation reduces the income domain. The economies in Group Two (France, Germany and Japan) display downward trending KN utilisation. The income gaps displayed usually have an increasing trend. Such trends appear to suggest that the capacity constraint becomes more stringent over time when there is a decrease in the utilisation of KN.

Comparing the KN utilisation and the Y trends in Figure 4.2 and 4.3, it is possible to reach a conclusion about the efficiency of an economy. An economy can be considered efficient when the income gap is rising with a low level of KN utilisation. For ease of comparison, the focus is on Group One (with an increasing usage of KN) and Group Two (with a decreasing usage of KN) economies.

Australia and Canada in Group One display an increase in KN utilisation. It is observed that the corresponding income gaps display a decreasing trend. France, Germany, and Japan in Group Two show a decrease in KN utilisation. These economies can be classified as efficient since the income gap is rising with a corresponding low level of KN utilization. The corresponding income gaps for the three economies in Group Two display an upward trend. Of the three economies, Japan is displaying a trend which best fits the description. Unemployment levels across the same time period are decreasing for the economies in Group One (see Figure 4.4). On the other hand, Germany, France and Japan (Group Two) display an increasing trend in the level of unemployment (see Figure 4.5).

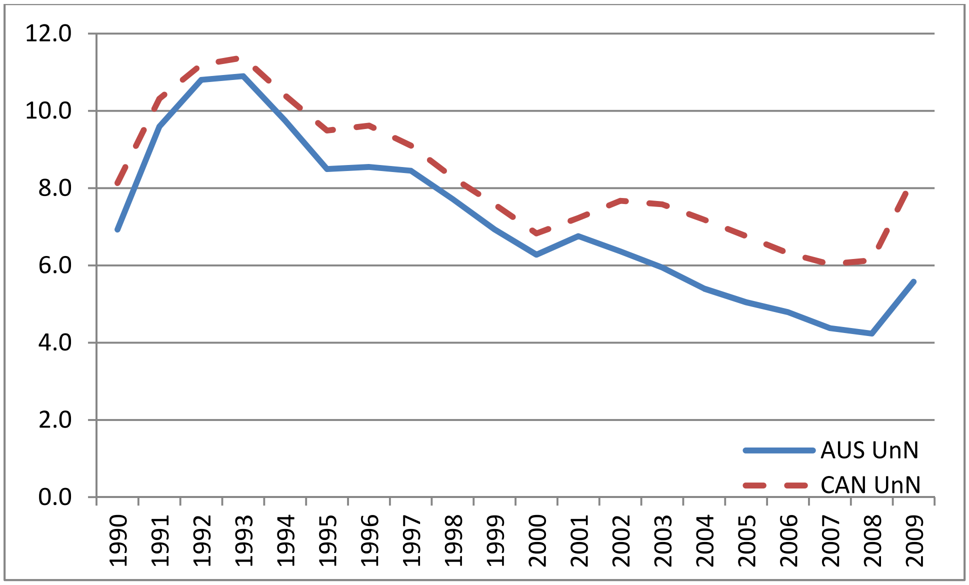


Figure 4.4: Unemployment Levels for Australia and Canada

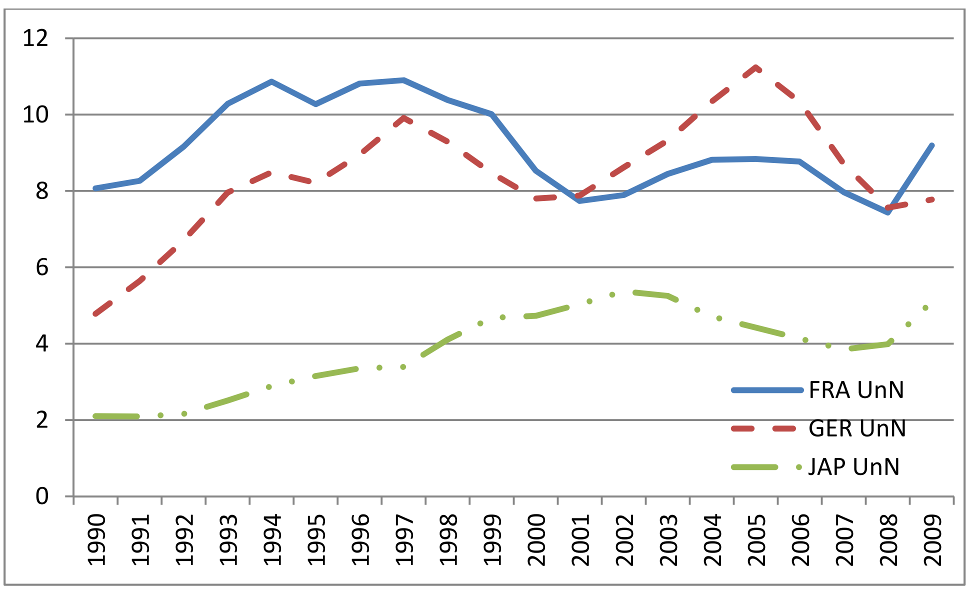


Figure 4.5: Unemployment Levels for France, Germany and Japan

The above discussion is summarised in Table 4.4 below. The utilisation of KN increases when income gap and unemployment are decreased, and vice-versa where the utilisation of KN is decreased when income gap and unemployment are increased.

Group	**KN Utilisation**	**Income Gap**	**Unemployment**
One (AUS and CAN)	Increasing	Decreasing	Decreasing
Two (FRA, GER, JAP)	Decreasing	Increasing	Increasing

Table 4.4: Trends of KN Utilisation, Income Gap and Unemployment for Group One and Two economies

To determine whether an economy is truly efficient, that is, with low KN utilization as Y rises, it might be appropriate to review the trade relations between selected economies. For this analysis, the Australia (Group One) and Japan (Group Two) economies are selected. Japan is ranked second in the list of top ten exporters to which Australia exports to[38] (see Table 4.5 below).

[38] http://www.dfat.gov.au/trade/focus/081201_top10_twoway_exports.html

Rank	Country	Share of Trade (%)
1	China	13.2
2	**Japan**	**12.3**
3	United States	10.3
4	Singapore	5.8
5	United Kingdom	5.3
6	Republic of Korea	4.7
7	New Zealand	4.6
8	Thailand	3.3
9	Germany	2.9
10	Malaysia	2.9

Table 4.5: Australia's Top 10 Two-Way Trading Partners

Source: Australian Department of Foreign Affairs and Trade

Similarly, Australia is ranked third, after China and the USA, in the list of importers from which Japan imports[39]. It appears that Australia is using more of its KN endowments to meet the export demands from Japan. This inference can be drawn because Australia's unemployment is falling, which results from more labour being employed for the production of these exports. Japan has a falling KN utilisation coupled with a widening income gap, because it has the option of producing less (which results from Japan importing from Australia). Unemployment in Japan is rising because goods are imported as opposed to being produced locally.

[39] http://www.washingtonpost.com/wp-dyn/articles/A40192-2005Jan26.html

Based on the discussion above, it is likely (but not conclusive) that Japan's prosperity (a rising income gap with increasing economic capacity) and its environmentally efficient behaviour may have been achieved at the expense of Australia's KN , for which there has been increasing usage.

Note that λ and λ' are the share of income to labour in both the 2- and 3-factor income models. And ϕ is the share of income to KN in the 3-factor income model. The calculated values are shown below in Table 4.6 for Group One and Two economies for the year 2009.

	λ	θ	λ'	θ'	ϕ
Group One					
AUS	0.54	0.46	0.50	0.45	0.05
CAN	0.58	0.42	0.52	0.41	0.07
Group Two					
FRA	0.6	0.4	0.55	0.41	0.04
GER	0.56	0.44	0.50	0.44	0.06
JAP	0.58	0.42	0.54	0.43	0.03

Table 4.6: Share of income to Labour (λ and λ') in both the 2- and 3-Factor Income Model

From Table 4.6 above, λ and λ' are in the range of 0.5 to 0.6, respectively. If the share of income to labour is higher than the other coefficients, that is the share of income to KM (θ and θ') and the share of income to KN (ϕ), then the economy relies more on L than on the other factor/s. Hence, labour productivity, wage policy, and initiatives toward increasing the economy's capacity are key determinants to ensuring that employment levels are maintained.

The range for ϕ in the sample of economies lies between 0.03 and 0.07. This range suggests that the share of income to KN is low relative to L. Note that the low estimated value (0.03) of ϕ is for Japan. This value is in line with the illustrative analysis above of trade between Australia and Japan. Japan is environmentally efficient, with a rising level of income but high unemployment. Australia is not environmentally efficient because KN utilization is rising with the falling level of income and low unemployment.

The capacity of an economy and the level of employment will be discussed in the next two chapters.

7. CONCLUSION

This chapter introduced the 3-factor income model, which includes KN as a consideration for economic growth. Issues pertaining to economic growth are of interest because they concern a nation's wealth and its people. Traditionally, such an expected growth path does not consider KN. If KN was considered in this growth model, the plausibility of a variation in the path of the economy cannot be ruled out. Economic progress is based on the propensity to save, capital accumulation, population growth rate and the expected growth path that an economy would take. Policy decisions are made depending on where an economy is expected to be in the future. Unfortunately, these same policy decisions tend to be made without consideration to KN. There will be changes in income from the internalisation of KN. In the next chapter, the Swan Solow growth model will be used to show how KN affects Y and how KN will alter the steady state from k^* (in the standard macroeconomic model) to k^{**} (in the environmental-macroeconomics model).

Chapter Five – Steady States of the Standard and Environmental-Macroeconomics Models

1. INTRODUCTION

In the previous chapter, an economy's capacity was defined in terms of the complete utilisation of the labour force (L_f). In this chapter, the economy's capacity is considered in terms of the steady state equilibrium (SSE) as explained in the early neoclassical work of Solow (1956) and Swan (1956). Steady state (S-S) literature is now outdated. For example, in contemporary macroeconomic models, technology is no longer regarded as exogenous; instead, it is considered endogenous. Nevertheless, the choice of the neoclassical growth model is favoured for reasons of illustrative convenience especially in terms of the analytics of point estimate. Furthermore, it is also noteworthy that the endogenous formulation [see Romer (1986)] is based on the neoclassical Swan-Solow (1956) framework.

The focus of this chapter is on the long-term analysis of both of the models. The chapter begins by defining the steady state, followed by a derivation of the steady states for both the standard macroeconomic and environmental-macroeconomics (EM) models. The standard macroeconomic model is based on the Cobb-Douglas (C-D) factor utilisation function. And the EM model is based on a 3-factor utilisation function, the third factor being environmental capital (KN). The steady states will be operationalised for the same group of selected Organisation for Economic Co-operation and Development (OECD) economies (which KN was empirically measured for). The outcome of the empirical evidence of the steady states based on the two models will be presented next. The chapter concludes with how the long-term trends of the economies relate to the economies' macroeconomic goals of inflation, employment, and GDP growth.

2. STEADY STATE EQUILIBRIUM (SSE)

The SSE in the Swan-Solow framework is the amount of capital accumulated that is just sufficient to meet the needs of capital (KM) depreciation and the entry of new workers. Capital accumulation is assumed to emerge directly from savings. In other words, savings (S) is equal to investment (I), S = I. Furthermore, the pertinent variables in the framework are described in per worker terms. These variables are as follows:

i. Capital per worker $k = \left[\frac{KM}{L}\right]$ (5.1)

ii. Savings per worker $s = \left[\frac{S}{L}\right]$ (5.2)

iii. Output per worker $y = \left[\frac{Y}{L}\right]$ (5.3)

The 2-factor [Y = f (KM, L)] C-D model is used to explain the relationship between k and y; and between k and s. That is,

$$y = \alpha k^{\theta} \tag{5.4}$$

$$s = \alpha \rho k^{\theta} \tag{5.5}$$

where α is the total factor productivity and ρ is the savings rate per worker.

The SSE can be derived in terms of a point estimate as:

$$\left[\frac{KM}{L}\right]^{*} = \left[\frac{\rho\alpha}{\delta+\eta}\right]^{\frac{1}{1-\theta}} \tag{5.6}$$

This scenario is illustrated in Figure 5.1 below.

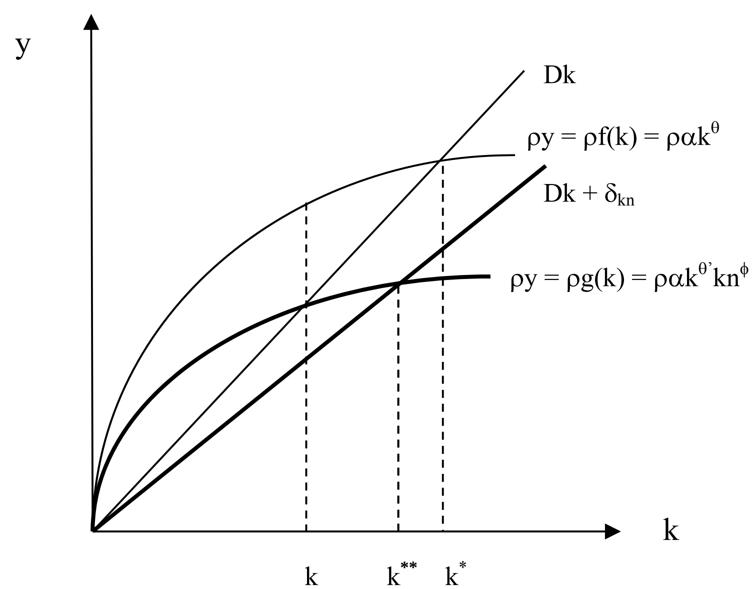


Figure 5.1: Steady State Equilibrium of the 2-Factor C-D Model (k^*) and the 3-Factor Model (k^{**})

In Figure 5.1, the curve labelled y = f (k) shows how the output per worker (y = Y / L) increases when the capital per worker (k = KM / L) is increased. When y = f (k) is multiplied by the savings ratio (ρ), the curve $\rho\alpha k^{\theta}$ is the result. The straight line from the origin describes the amount of KM stock replacement that is required for the depreciation of existing KM. It corresponds to the equation Dk, where (D = δ + η), δ is the rate of KM depreciation and η is the rate of entry of new workers. The point of intersection between the straight line Dk and the curve describing savings $\rho\alpha k^{\theta}$ is the SSE, k^{*}. The SSE is defined by the quantity of KM per worker as shown in equation (5.3) above. The derivation of the SSE is presented in Appendix 5.1 of this chapter. Comparing k^{*} and k, k is the current level of KM per worker.

When the 3-factor [Y = g (KM, L, KN)] model is used, there will be one more variable in addition to the three variables (5.1, 5.2, 5.3) discussed earlier. The result is the KN per worker, kn = (KN / L). Because KN is measured on the same scale as KM (assumed), it can be costed and depreciated in the same way as KM. In this revised model, the curve (bold) $\rho\alpha k^{\theta'} kn^{\phi}$ is the result when y = g (k) is multiplied by the savings ratio (ρ). Please refer to Figure 5.1. With a new variable kn, there is a new parameter ϕ which is the share of income that accrues to KN. The straight line (bold) from the origin corresponds to the equation $Dk + \delta_{kn}$, where δ_{kn} is the depreciation of KN. The SSE is the point of intersection between the straight line $Dk + \delta_{kn}$ and the curve $\rho\alpha k^{\theta'} kn^{\phi}$. The SSE is defined by the quantity for KM per worker:

$$\left[\frac{KM}{L}\right]^{**} = \left[\frac{\rho\alpha\gamma^{\phi}}{D+\gamma\delta_{KN}}\right]^{\frac{1}{1-\theta'-\phi}} \qquad (5.7)$$

The derivation of the revised SSE is presented in Appendix 5.2 of this chapter.

It is apparent from Figure 5.1 that there are changes to the SSE. In the 2-factor C-D model, the current level of k and the SSE is (k, k^*). Comparing this model with the 3-factor model, the respective levels are (k, k^{**}). SSE is reached earlier in the 3-factor model relative to the 2-factor model because allowance has been made for KN. It is now fitting to compare the observed trend of k with the SSE. Let's consider three possible scenarios. For scenario A, the economy's observed level of capital accumulation is lower than that required for the SSE $(k < k^*)$, that is $(k^* / k) > 1$. The economy is experiencing savings surpluses and is under-utilising its available resources. There is capacity available in the economy. In scenario B, the economy's observed level of capital accumulation exceeds the SSE $(k > k^*)$ and $(k^* / k) < 1$. In this context, the economy is experiencing a savings deficit and is over-utilising its available resources. The economy may be over-capitalised and have a possibility of rising inflation. In scenario C, the economy is at the SSE $(k = k^*)$ and $(k^* / k) = 1$.

Please see Table 5.1 for the definition of these contexts.

Scenarios	Accumulated capital stock relative to SSE in both the 2-factor (k^*) and 3-factor model (k^{**})	State of the economy
A	$(k^* / k) > 1$ / $(k^{**} / k) > 1$	Excess Capacity
B	$(k^* / k) < 1$ / $(k^{**} / k) < 1$	Beyond Capacity
C	$(k^* / k) = 1$ / $(k^{**} / k) = 1$	Steady State

Table 5.1: Table Illustrating the Three Different Scenarios for the Economy

3. EMPIRICAL ILLUSTRATION OF SSE

For an illustration of the SSE for both the 2-factor and 3-factor model, the following data were used:

i. ρ is estimated as the savings rate per worker
ii. α is the total factor productivity
iii. δ is the rate of depreciation of KM
iv. η is the entry of new workers into the workforce (or the annual growth of labour)
v. γ is KN as a factor of KM
vi. δ_{KN} is the depreciation of KN which is estimated using a method outlined in Thampapillai and Hanf (2000). Here P_{KN} is defined as (ϕY / KN). Recall from Chapter 4 that ϕ is the share of Y that accrues to KN. Then δ_{KN} is ($P_{KN} - i_{KN}$) and is based on the premise that the price of any capital is the sum of the interest rate

and the depreciation. As in Thampapillai and Hanf (2000), the interest rate was assumed to be the same as that of KM.

Next, the following steps were used to estimate the SSE values of capital accumulation prevailing at k^* and k^{**}:

i. From the Swan-Solow model, k is estimated as KM per worker employed, that is (KM / L)

ii. Equation (4.10) is used to estimate the initial size of the capital stock for the first year. Equation (4.11) is used to estimate the size of the capital stock for subsequent years. The C-D factor utilisation function, which displays constant returns, is a valid descriptor of the distribution of Y between KM and L, in other words $Y = \alpha\ KM^{\theta}\ L^{\lambda}$. Hence, the total factor productivity is

$$\alpha = [Y / (KM^{\theta}\ L^{\lambda})] \tag{5.8}$$

iii. Based on the Swan Solow model of economic growth and using information gathered from the steps above, the estimated steady state value of KM per worker $[KM / L]^*$ or k^* is defined as (see Appendix 5.1 for workings):

$$\left[\frac{KM}{L}\right]^* = \left[\frac{\rho\alpha}{\delta+\eta}\right]^{\frac{1}{1-\theta}} \tag{5.9}$$

where δ, the rate of depreciation of KM is 1/30 because KM is assumed to have a lifespan of 30 years. The variable η is the entry of new workers into the workforce (or the annual growth of labour). The savings rate (ρ) per worker and the national savings (S) are defined as S = GDP – C – G and ρ = (S / GDP). Here, α is as shown in Equation (5.1)

iv. With the measurement for KN derived in Chapter 4, a steady state for the 3-factor utilisation function can be obtained. The steady state k^{**} is the following (see Appendix 5.2 for workings):

$$\left[\frac{KM}{L}\right]^{**} = \left[\frac{\rho\alpha\gamma^{\phi}}{D+\gamma\delta_{KN}}\right]^{\frac{1}{1-\theta'-\phi}} \tag{5.10}$$

The new parameters in Equation (5.10) are the following: ϕ is the share of Y that accrues to KN; D is a constant, that is (δ+η); γ = KN / KM, where KN is a factor of KM; and δ_{KN} is the depreciation of KN.

In summary, the steady states for the C-D factor utilisation function (k^*) and the 3-factor utilisation function (k^{**}) and the estimation of KN are reproduced below:

	Estimation of variables
2-factor (k^*)	$\left[\frac{KM}{L}\right]^* = \left[\frac{\rho\alpha}{\delta+\eta}\right]^{\frac{1}{1-\theta}}$
3-factor (k^{**})	$\left[\frac{KM}{L}\right]^{**} = \left[\frac{\rho\alpha\gamma^{\phi}}{D+\gamma\delta_{KN}}\right]^{\frac{1}{1-\theta'-\phi}}$
KN	$KN = KM^{\frac{\theta-\theta'}{\phi}} L^{\frac{\lambda-\lambda'}{\phi}}$

Table 5.2: Steady states k^*, k^{**}, and Environmental Capital

The standard macroeconomic model will be based on the C-D factor utilisation function with k^* as the steady state. The EM model will be based on the 3-factor (KN internalised) utilisation function with k^{**} as the steady state. Economic models are meaningful only if they are applied. Both the standard macroeconomic model and the EM model (based on the 3-factor utilisation function) are now established with their SSE. The next section will operationalise both of the models via time-series empirical results on selected OECD economies.

4. STANDARD MACROECONOMIC MODEL VERSUS ENVIRONMENTAL-MACROECONOMICS (EM) MODEL

The standard macroeconomic model and the EM model were tested on 11 selected OECD economies. The economies are Australia, Canada, France, Germany[40], Japan, Korea, Mexico, New Zealand, Norway, the United Kingdom, and the USA. The OECD database was used because it had a complete set of national income accounts (expenditure and income accounts) from 1980 to 2009.

The following approach is used to analyse the data. The year 1980 is the initial period, and 2009 is the terminal period. The rationale is as follows. The second oil crisis in 1979 pushed oil prices in real terms to an all-time high. In fact, the Iran-Iraq war nearly stopped oil production in Iran. This scenario led to an energy crisis with a strong demand for oil and, in turn, pushed oil prices up. It was not until the Global Financial Crisis almost 30 years later, in 2008, that oil prices started peaking again. Thus, 1980 and 2009 were years that followed immediately and respectively from an energy crisis and a financial crisis. Using 1980 and 2009 as the years for comparison is appropriate because both were years that immediately followed a crisis. Thus, 1980 is used as the base year for comparison and 2009 is used as the current state of the economy. The current state of the economy in 2009[41] will dictate its subsequent trajectory into the future.

[40] The time period for Germany's data was from 1992 to 2009 because this time interval was the period after the unification of East and West Germany.
[41] Another reason why the year 2009 was used as opposed to a later year was that the complete set of time series data at the time of empirical analysis was complete only until 2009.

The selected economies are classified according to the state of affairs in both the initial and terminal periods. From Table 5.1, there are three possible scenarios: Scenario A, in which there is excess capacity, with $(k^* / k) > 1$; scenario B, in which the economy is operating beyond capacity, with $(k^* / k) < 1$; and scenario C, in which the economy is operating at its steady state, with $(k^* / k) = 1$. A comparison is made to each economy for 1980 as well as 2009 with respect to the scenario that it is in. This comparison is conducted for both steady state ratios of the standard model (k^* / k) and the EM model (k^{**} / k).

I. Empirical Results

The empirical results of the standard macroeconomic (k^* / k) model and the EM (k^{**} / k) model are presented below in Tables 5.3 and 5.5. The observation is made depending on whether an economy is operating with excess capacity $(k^* / k) > 1$ or beyond capacity $(k^* / k) < 1$. The significance being in determining if the steady state of an economy has changed or stayed the same post-crisis. This comparison is made for the time periods of 1980 and 2009. Table 5.3 shows the steady state ratios of the economies based on the standard model (k^* / k).

Economies / Year	1980		2009	
	$(k^*/k) > 1$ (Excess Capacity)	$(k^*/k) < 1$ (Beyond Capacity)	$(k^*/k) > 1$ (Excess Capacity)	$(k^*/k) < 1$ (Beyond Capacity)
Australia		✓		✓
Germany		✓		✓
Mexico		✓		✓
New Zealand		✓		✓
Canada	✓		✓	
France	✓		✓	
Korea	✓		✓	
Norway	✓		✓	
United Kingdom	✓		✓	
Japan	✓			✓
USA	✓			✓

Table 5.3: Standard Macroeconomic Steady State Ratio (k^* / k) of Economies in 1980 and 2009

Based on Table 5.3 above, the selected economies can be categorised into four broad groups.

Group	1980	2009	Economies
One	$(k^* / k) < 1$ (Beyond Capacity)	$(k^* / k) < 1$ (Beyond Capacity)	Australia, Germany, Mexico, New Zealand
Two	$(k^* / k) > 1$ (Excess Capacity)	$(k^* / k) > 1$ (Excess Capacity)	Canada, France, Korea, Norway, United Kingdom
Three	$(k^* / k) > 1$ (Excess Capacity)	$(k^* / k) < 1$ (Beyond Capacity)	Japan, USA
Four	$(k^* / k) < 1$ (Beyond Capacity)	$(k^* / k) > 1$ (Excess Capacity)	N.A.

Table 5.4: Categorising Economies Based on the Steady State Ratio (k^* / k) of Economies in 1980 and 2009 for the Standard Macroeconomic Model

Economies in Group One and Group Two remained in the same capacity state over both time periods; after both crises, Group One economies appear to be operating at beyond capacity while the result for those in Group Two being excess capacity. Japan and the USA, which were in Group Three, were the only two economies that moved from operating with excess capacity to operating beyond capacity after both crises. Based on the standard macroeconomic model, it can be argued that Japan and the USA were the two economies that had changes in their economic capacity as a result of a crisis. None of the economies falls into Group Four.

When KN is internalised in the standard macroeconomic model, the model is revised to the EM model. Table 5.5 shows the steady state ratios of the economies based on the EM model.

Economies / Year	1980		2009	
	$(k^{**}/k) > 1$ (Excess Capacity)	$(k^{**}/k) < 1$ (Beyond Capacity)	$(k^{**}/k) > 1$ (Excess Capacity)	$(k^{**}/k) < 1$ (Beyond Capacity)
Australia		✓		✓
France		✓		✓
Germany (from 1992)		✓		✓
Japan		✓		✓
Mexico		✓		✓
New Zealand		✓		✓
United Kingdom		✓		✓
Norway	✓		✓	
Canada	✓			✓
Korea	✓			✓
USA	✓			✓

Table 5.5: Environmental-Macroeconomics Steady State Ratio (k^{**} / k) of Economies in 1980 and 2009

Based on Table 5.5 above, the selected economies can also be categorised into three broad groups.

Group	1980	2009	Economies
One	$(k^{**} / k) < 1$ (Beyond Capacity)	$(k^{**} / k) < 1$ (Beyond Capacity)	Australia, France, Germany, Japan, Mexico, New Zealand, United Kingdom
Two	$(k^{**} / k) > 1$ (Excess Capacity)	$(k^{**} / k) > 1$ (Excess Capacity)	Norway
Three	$(k^{**} / k) > 1$ (Excess Capacity)	$(k^{**} / k) < 1$ (Beyond Capacity)	Canada, Korea, USA
Four	$(k^{**} / k) < 1$	$(k^{**} / k) > 1$	N.A.

Table 5.6: Categorising Economies Based on the Steady State Ratio (k^{**} / k) of Economies in 1980 and 2009 for the Environmental-Macroeconomics Model

Economies in Group One and Group Two remained in the same capacity state over both time periods: after both crises Group One economies (Australia, France, Germany, Japan, Mexico, New Zealand, and the United Kingdom) appear to be operating at beyond capacity while the result for Group Two with only one economy (Norway) being one of excess capacity. Canada, Korea and the USA in Group Three moved from operating with excess capacity to beyond capacity, and based on the EM model, were the only economies with economic changes in capacity as a result of a crisis.

The grouping of the economies changed when the EM model was used as opposed to the standard macroeconomic model (Tables 5.4 and 5.6). In the standard macroeconomic model, Canada and Korea moved from Group Two to Group Three in the EM model. France and the United Kingdom moved from Group Two in the standard macroeconomic model to Group One in the EM model. Japan moved from Group Three in the standard macroeconomic model to Group One in the EM model. Norway became the only economy in Group Two. The inconsistency of such observations between the two models suggests the plausibility of policy domains being incorrectly identified should the standard macroeconomic model be employed.

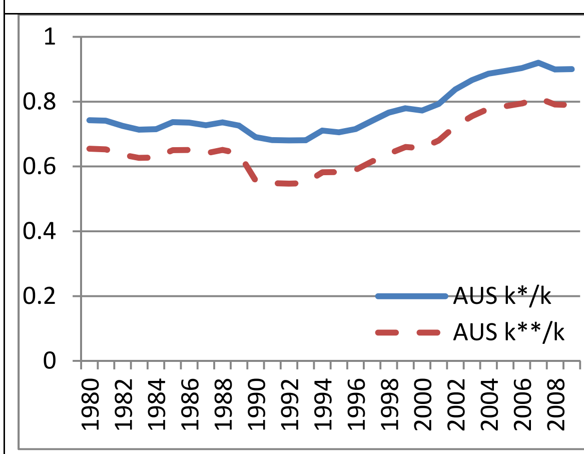
The above discussion was based on the steady state of the economy in 1980 and 2009. For a better appreciation of the differences when the EM model is applied, the following sub-section shows the presentation of the economies from the time period 1980 to 2009. In the steady state, k^* (of the standard macroeconomic model) will always be greater than

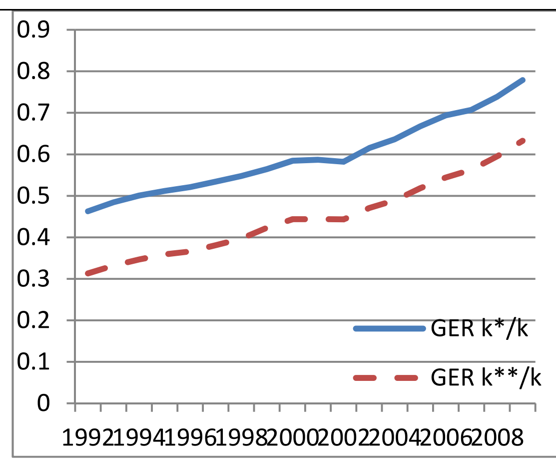
k^{**} (of the EM model). This scenario causes two different steady states when comparing the standard macroeconomic model and the EM model.

II. Presentation of the OECD Economies (Time-Series)

The selected OECD economies are graphed using the steady state ratios of [(k^* / k), (k^{**} / k)]. Please refer to Table 5.1 for a description of what each of the ratios represents. The ratios are obtained for all of the selected OECD economies over the time period of 1980 to 2009. Both ratios [(k^* / k), (k^{**} / k)] are graphed on the same X-Y plot, with the steady state ratio on the vertical axis and time on the horizontal axis. This strategy allows for a comparison between the two ratios across the two different models. The following shows the economies grouped according to the trends displayed.

Group One – Upward Linear Trends Beyond Capacity



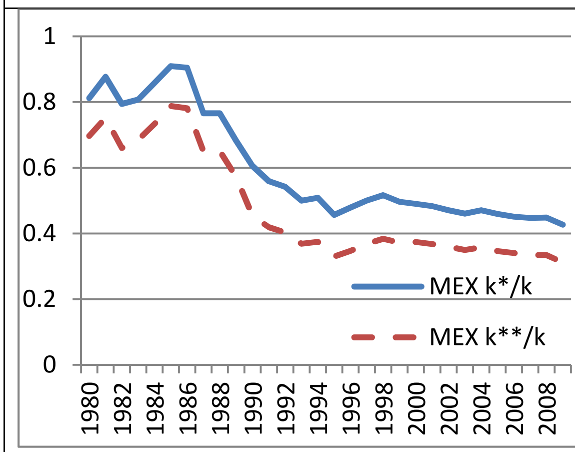


Australia and Germany operate beyond capacity (the ratio is less than one) for both the standard macroeconomic and EM models. The linear upward trend demonstrates a freeing up of capacity in the economies.

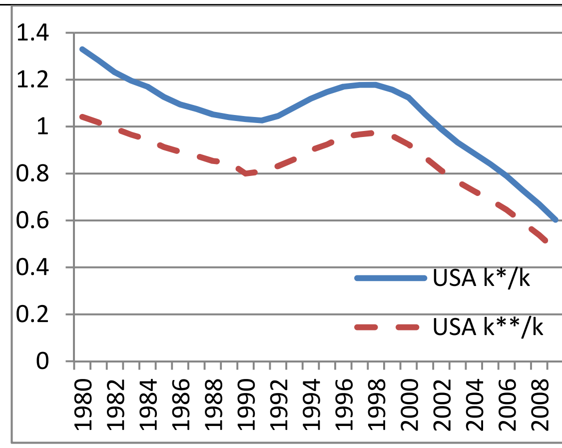
Australia is tending toward steady state (a ratio value of one) in the standard macroeconomic model. However, the Australian economy remains at beyond capacity (at a ratio of less than one) in the EM model. There is a divergence of the two graphs toward 2009.

Germany remains operating beyond capacity (at a ratio of less than one) in both models. Furthermore, Germany's graphs appear to be more separate relative to Australia's graphs.

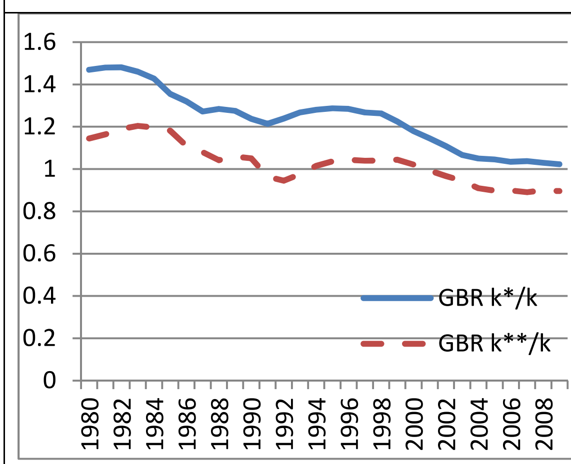
Group Two – Downward Trends Beyond Capacity



Mexico operates beyond its capacity (the ratio is less than one). There is a convergence of both graphs in 1987.

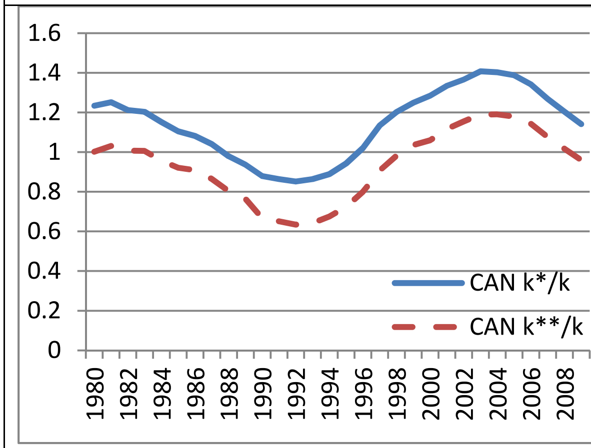


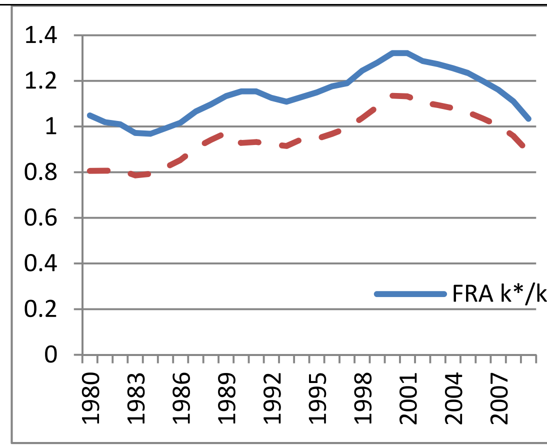
The USA has been using its spare capacity since 1980 and operates beyond its capacity (the ratio is less than one) from 1998 to 2009. There is an observed convergence of both graphs toward 2009.



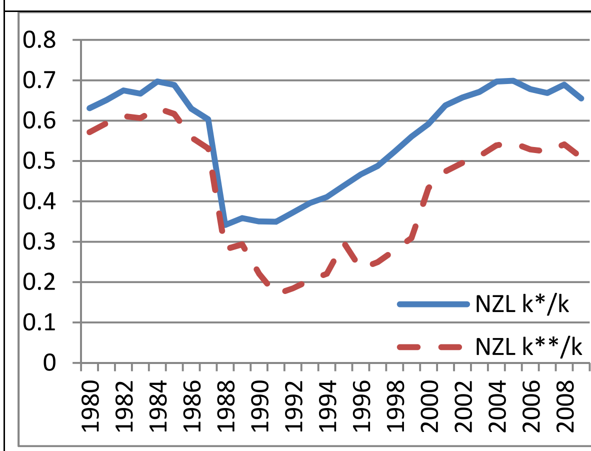
In the standard model, the United Kingdom (GBR) is using its excess capacity and tending toward a steady state (a ratio value of one). However, in the EM model, GBR appears to be using up the excess capacity and operates at beyond capacity (at a ratio of less than one). The graphs of both models converge towards 2009.

Group Three – Cyclical Trends





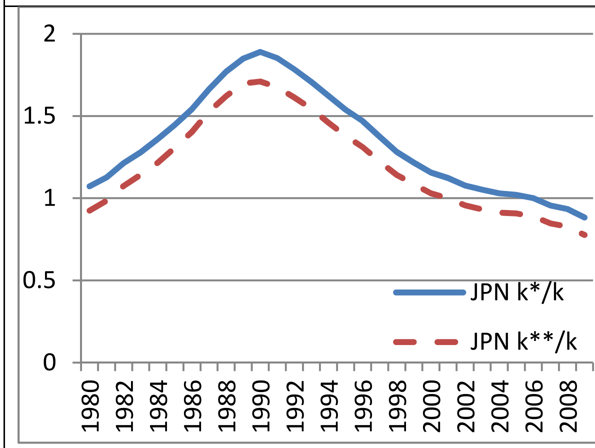
Canada and France displayed similar cyclical trends. In the standard model, both Canada and France were operating with excess capacity (a ratio of greater than one) before tampering and hovering near steady state (a ratio value of one). In the EM model, the economies were operating at beyond capacity (a ratio of less than one) but accumulated capacity and moved to operating with excess capacity (a ratio of more than one). A slight convergence of the two graphs can be observed in both economies when nearing 2009.

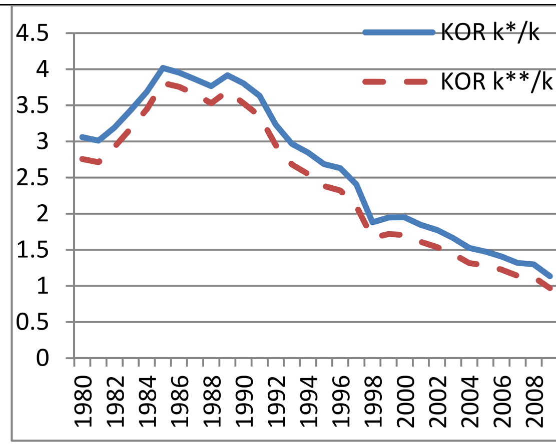


New Zealand's economy is consistently operating beyond capacity. It operates at beyond capacity (at a ratio of less than one) over the observed period. The value of the ratio for New Zealand is the lowest observed amongst all of the selected economies. This fact implies that the economy is operating beyond its means. It is observed to be over-stretching its capacity between 1987 and 2000 when it was operating in a deep trough. The deep trough is more significant in the EM model.

Both graphs converged in 1987 and 1988. After the observed convergence, the EM model diverged away from the standard model substantially. In fact, this divergence is the greatest divergence observed amongst all of the selected economies. The diverging lines show that impressive economic growth (operating beyond capacity) has been accompanied by the utilisation of KN at an increasing rate.

Group Four – Peaked Economies with Excess Capacity

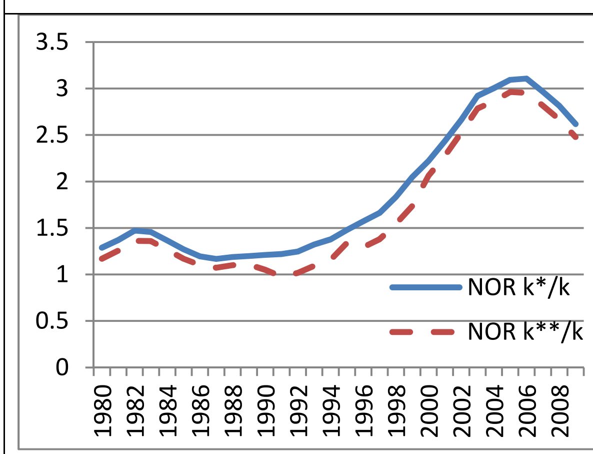




Both Japan and Korea displayed a peak in the steady state ratio between 1985 and 1991. The economies were operating with excess capacity (a ratio of greater than one). The value of the ratio for Korea is the highest observed ratio value amongst all of the selected economies. Although it is on a downward trend, this ratio value reflects the level of excess capacity in Korea's economy.

Toward the year 2009, Japan's economy moved to beyond capacity (a ratio of less than one); and Korea edged towards steady state (a ratio value of one).

The graphs for both the standard macroeconomic model and the EM model are very close when mapped to each other.



Norway's economy is consistently operating within capacity. It stays in the excess capacity region (a ratio of greater than one) region over the observed period. The value of the ratio is the second highest value amongst the selected economies. Furthermore it is on an upward trend which reflects a build-up of capacity in its economy.

The graphs for both the standard macroeconomic model and the EM model

	converge and can be very closely mapped to each other.

Figure 5.2: Grouping of Economies Based on the Steady State Ratios of (k^{*} / k) and (k^{**} / k)

All of the selected OECD economies shown in Figure 5.2 show that the ratio of (k^{**} / k) in the EM model will always reach a steady state earlier than the ratio of (k^{*} / k) in the standard macroeconomic model. The line of (k^{**} / k) is always below that of (k^{*} / k) which shows that the capacity of an economy can be overstated if KN is not taken into consideration. Although this observation has been reviewed for the past 30 years, it does present to the policy maker either one of two possible paths that an economy could have taken at the time of policy making, viz: the path that was (k^{*} / k) versus the path that should have been (k^{**} / k).

The long run analysis of the model discussed in this section has been made with respect to the steady state ratios of the selected OECD economies. Based on the discussion, an economy can either operate with excess capacity available, at beyond capacity, or at steady state. The capacity available in an economy can be determined by how an economy's long-term macroeconomic goals (inflation, employment, and per capita GDP) are addressed such as which goal(s) (if any) have priority or whether all of the goals have equal precedence. The next section will revisit some of the key points that relate to long run macroeconomic goals.

5. LONG RUN MACROECONOMIC GOALS of INFLATION, EMPLOYMENT, and GDP GROWTH

As demonstrated by the empirical results presentation, macroeconomic goals ought to be properly reviewed and adjusted according to the immediate priorities of an economy. This task is especially critical if there is a chance that policy ranges are not correctly identified. This chapter will conclude with a re-examination of the long run macroeconomic goals of inflation, employment, and per capita GDP, which was first discussed in Chapter One.

Before discussing each of the long run macroeconomic goals, it is important to differentiate the different time periods in macroeconomics. Please refer to Figure 5.3 below.

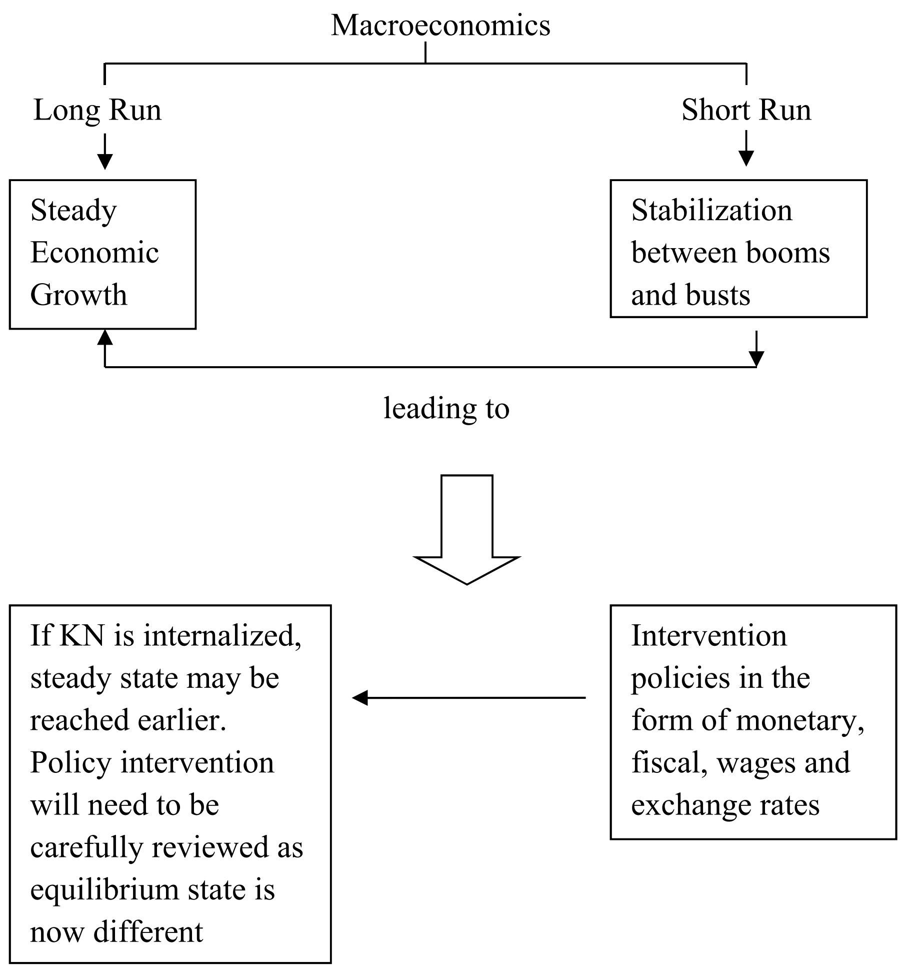


Figure 5.3: Long Run and Short Run of Macroeconomics

In the long run, an economy is focused on steady economic growth. In the short run, there will be cycles of booms and busts which over the long run are, however, expected to smooth over and result in steady economic growth. Reducing such volatility in the economy will instill confidence and will reduce uncertainty for investors and citizens alike. Effective surveillance and timely analysis of macroeconomic trends ensure that policies are shaped toward macroeconomic stability. Macroeconomic stability lies at the core of economic policy formulation in all economies. The macroeconomic trends that the policy makers are concerned with include the GDP, inflation, unemployment, budget deficits, and the balance of payments. For the purpose of this analysis, the focus will be on inflation, employment, and per capita GDP.

Inflation, employment and per capita GDP were discussed in Chapter One. Inflation refers to the overall increase in the prices of goods and services in an economy, and can be attributed to an increase in the quantity of money. Economists' definition of full employment could include a reference to existence of unemployment in terms of frictional and structural categories. This level of unemployment is an economy's natural rate of unemployment. Per capita GDP is the level of growth determined by the amount of goods and services produced divided by the population of an economy. A higher level of GDP growth can translate to a higher level of living standard for the citizens. From the long run analysis, the macroeconomic goals of inflation, employment and per capita GDP can suffice to move an economy to steady state. However, by taking KN into consideration, a different steady state will arise. Hence, there should be an allowance for KN when considering sustainable growth.

In the long run, an economy is expected to exhibit steady economic growth. The factor utilisation functions discussed in Chapter Four are the compelling forces that drive this observation. The economics of growth or growth economics are of interest to policy makers. In an ideal situation, equilibrium in the long run would tend toward or be at a steady state. Economic growth would be exogenously determined, with capital accumulation becoming less significant, and technological progress becoming more dominant as a factor for economic growth. Technological progress is often measured by the Solow residual or the total factor productivity (TFP). TFP is enhanced as new capital becomes more valuable than old capital. This is because new capital is based on new technology improving over time. Therefore, it can be argued that technological progress and other external factors may be the main sources of economic growth in the long run by being add-ons to steady state changes, which invariably will affect macroeconomic goals in the long run.

According to Holt (2005), natural capital is based on a dynamic relation between a physical and a biotic environment (which can be unpredictable). The Bruntland Report proposed a change in the exploitation process of resources that would be consistent with future as well as present needs. Hence, there should be moderation of the increase in economic growth. It is crucial to measure the effects of economic activities that are sustainable and resilient with the ecosystems and natural resources. Because of the level of uncertainty, it may be difficult to know the effects of economic growth on the resilience of the environment and natural resources (Holt, 2005).

The challenges for policy makers with respect to macroeconomic goals are as follows. First, is inflation set within acceptable levels for policies to be effective? Second, can greater employment be achieved without significantly impacting inflation? Third, how much is an economy allowed to grow? To sustain natural resources, reduce environmental degradation, and protect a fragile ecosystem for future generations, a steady state should consider KN in addition to the three macroeconomic goals. Sustainability is incorporated by focusing on the macroeconomic and policy outcomes, and on the uncertainties in an economy.

6. CONCLUSION

The aim of this chapter is to present a steady state analysis of the standard macroeconomic model and the EM model. It has been demonstrated that the policy ranges can be incorrectly identified. In addition, the capacity of an economy can be overstated without appropriate consideration for KN. However, should KN be taken into consideration, there are two possible paths that an economy could take at the time of policy making namely, the path of the EM model and the path of the standard macroeconomic model. In the long run, macroeconomic stability is central to economic policy formulation in all economies. Policy formulation must consider the capacity of an economy with respect to the long run macroeconomic goals of maintaining inflation within an agreed band and ensuring low unemployment and a smooth GDP growth.

The next chapter will evaluate these macroeconomic goals with respect to the steady state ratios of the selected OECD economies for both the standard macroeconomic model and the EM model.

Chapter Six – Macroeconomic Goals and Steady States

Short Run Policy Analysis – A Methodology

1. INTRODUCTION

In the Swan-Solow (SS) framework, which is discussed in Chapter Five, the steady state equilibrium (SSE) is the amount of capital (KM) accumulated that is just sufficient to meet the needs of depreciation and the entry of new workers. Hence SSE is defined by the quantity of KM per worker. This chapter offers an evaluation of the relationship between SSE and the macroeconomic policy variables or goals (inflation, employment and per capita GDP), and of the fact SSE can explain or account for such variables or goals. Thus, the independent variable is the SSE and the dependent variables are the macroeconomic goals. This relationship will be tested with both the standard macroeconomic model and the environmental-macroeconomics (EM) model to determine if the relationship differs depending on which model is used.

This chapter will begin by discussing the macroeconomic goals and an economy's SSE. An explanatory relationship will be formalised between the macroeconomic goals and the SSE for the selected Organisation for Economic Co-operation and Development (OECD) economies. Panel regression and linear regression (for economies that cannot be explained using panel regression) will be used to explain such relationships. Snapshots for the year 2009 of the economies for both the standard macroeconomic and EM models will be presented next. On the basis of the ascertained relationships, this chapter concludes with findings from the snapshots.

2. SHORT RUN MACROECONOMIC GOALS AND ECONOMIES' STEADY STATE EQUILIBRIUM (SSE)

In the short run[42], macroeconomic goals are concerned with pricing and employment, that is short-run economics. To attain the desired levels of macroeconomic goals, an economy will either use up capacity or free up capacity. An economy must trade-off between the short run macroeconomic goals to arrive at a steady state or to approach a steady state. A steady state can demand levels of inflation and employment that may not adhere to initial expectations. The short run macroeconomic goals of inflation and employment levels will, in turn, shape the long run macroeconomic goal of GDP growth. Most economies would prefer a stable GDP growth because this type of growth provides stability, injects confidence for investors and ensures that employment levels are sustained.

Economic growth is endogenously attributed to the accumulation of an economy's physical capital in the short run. An economy's capital accumulation is determined by its savings rate as well as by the rate of capital (KM) depreciation. The savings rate is the proportion of income that is used towards greater KM investment in the current time period as opposed to deferring the proportion of this income for future consumption. Although increased expenditure toward productivity (for example, increased spending on education and training) can lead to a higher growth of output per labour, these considerations do not necessarily translate to a sustained growth of output per labour.

[42] The distinction between short-run, long-run and the very long-run is addressed by point estimate analysis – which makes steady state a moving target for each time period as opposed to the steady state being a target for policy makers in the very long run. Therefore, the gap between the relative position of the economy and the steady state varies for each time period.

In this framework, steady state occurs when the savings rate is equal to the rate of replacement of manufactured capital (KM). Figure 6.1 below shows the capacity of an economy relative to its SSE for both the standard macroeconomic (Y^*) and EM (Y^{**}) models.

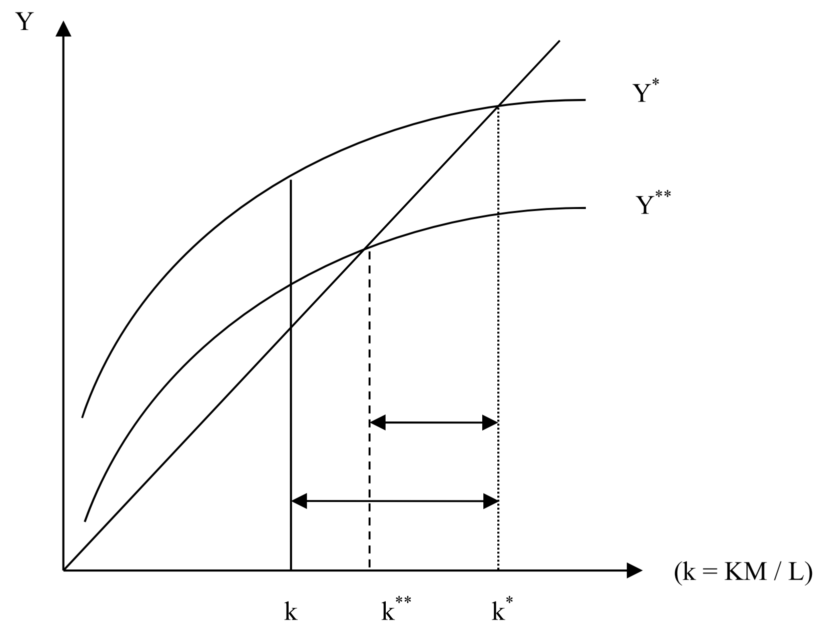


Figure 6.1: Capacity of an Economy Relative to Steady State Equilibrium (SSE)

The variables k^* and k^{**} are the SSE for the standard macroeconomic and the EM models respectively, and k is the current level of capital per worker. Figure 6.1 illustrates the level of excess capacity in an economy, namely, (k^* - k) for the standard macroeconomic model and (k^{**} - k) for the EM model. Note that if [($k > k^*$), ($k > k^{**}$)], then the capacity in terms of capital per worker is exceeded.

Each of the variables of the macroeconomic goals, namely, inflation (π), employment (N) and per capita GDP, will be a function of an economy's capacity. These relationships are formalised based on regression analysis.

Regression analysis is used to help understand how the value of the dependent variable changes when the independent variables are varied. Specific to this analysis, the dependent variables are the variables of the macroeconomic goals π, N and per capita GDP. The independent variable is the economy's steady state ratios [(k^* / k), (k^{**} / k)]. (Please refer to Table 5.1 for the definitions of the steady state ratios.) Depending on which macroeconomic goal is the dependent variable, the other two macroeconomic goals will be assumed to be constant. For example, if π is the macroeconomic goal, then the other two macroeconomic goals of N and per capita GDP will be assumed to be constant. This scenario leaves a single variable, the economy's capacity, as the determining variable that influences π. The analysis is now simplified to a single variable relationship, for which each macroeconomic goal will be directly affected by the steady state ratio of an economy.

For a selected economy, the following table illustrates the respective dependent (row, Y) variables with respect to the independent (column, X) variables.

	Inflation, π	**Employment, N**	**Per Capita GDP**	**Steady State Ratios [(k^* / k), (k^{**} / k)]**
Inflation, π		Constant	Constant	Variable
Employment, N	Constant		Constant	Variable
Per Capita GDP	Constant	Constant		Variable

Table 6.1: Macroeconomic Variables with respect to an Economy's Steady State Ratios

From Table 6.1, each variable of the macroeconomic goals will be directly determined by an economy's steady state ratio. Note that the steady state ratio [(k^* / k), (k^{**} / k)] differs depending on whether it is the standard macroeconomic model or the EM model.

The economy's steady state is calculated via a ratio (see Table 5.1), and the values for each variable of the macroeconomic goals are computed via the ratio of the current year's (t) value to past year's (t-1) value. This computation ensures consistency in the calculation of all of the variables and ensures that the values are positive for the operation of Ln. Because the present year values are weighted against the prior year's values, a ratio of greater than one represents an increase in the value of the variable and a ratio of less than one represents a decrease in the value of the variable. Logs of the ratios are taken (or ln) to scale the ratios to their natural forms. Thus, for each of the variables, the computation is as follows:

Inflation, π	**Employment, N**	**Per Capita GDP**	**Steady State Ratios [(k^* / k), (k^{**} / k)]**
$\left[\dfrac{Deflator_t}{Deflator_{(t-1)}}\right]$	$\left[\dfrac{Employment_t}{Employment_{(t-1)}}\right]$	$\left[\dfrac{GDPpercapita_t}{GDPpercapita_{(t-1)}}\right]$	Standard Model $\left[\dfrac{k^*}{k}\right]$ Environmental Model $\left[\dfrac{k^{**}}{k}\right]$

Table 6.2: Measurement Ratios for Each Macroeconomic Variable and Steady State

In the OECD iLibrary, inflation is proxied by the GDP Deflator; employment is Total Employment; and the per capita GDP is the GDP divided by the total population. The general equations are reduced to a single variable equation for which each of the macroeconomic goals will be directly determined by the economy's steady state ratio. For the year 2009, the reduced equation that relates an economy's steady state ratio to each of the macroeconomic goals would be as follows.

t = 2009	**Standard Model**	**EM Model**
Inflation, π	Ln π = a + Ln (k^* / k) where a = Ln N + Ln GDP	Ln P = $a^{'}$ + Ln (k^{**} / k) where $a^{'}$ = Ln N + Ln GDP
Employment, N	Ln L = b + Ln (k^* / k) where b = Ln π + Ln GDP	Ln L = $b^{'}$ + Ln (k^{**} / k) where $b^{'}$ = Ln π + Ln GDP
Per Capita GDP	Ln GDP = c + Ln (k^* / k) where c = Ln π + Ln N	Ln GDP = $c^{'}$ + Ln (k^{**} / k) where $c^{'}$ = Ln π + Ln N

Table 6.3: Simplified Equations of Macroeconomic Variables and Steady State Ratios

3. PANEL REGRESSION FOR THE OECD ECONOMIES

The 11 selected OECD economies are Australia, Canada, France, Germany[43], Japan, Korea, Mexico, New Zealand, Norway, the United Kingdom, and the USA. The selected time period is from 1980 to 2009. The data are multi-dimensional because there are multiple phenomena observed over multiple time periods for each of the economies. When such a phenomenon is observed, it is best to use panel data and to run a panel regression. Because panel data displays both cross-sectional and time-series dimensions, it is a more complex application compared to the simple cross-sectional or time-series data sets.

It is typically recognised that panel data possess several advantages. One advantage is that it allows for a larger number of data points, which is beneficial because there is no need to go very far back into historical data points. This reduces measurement errors that can arise from a lack of data because the time interval will be restricted to the parameters of the analysis. Another advantage is that panel data can capture unobserved heterogeneity (variances) of the variables. This property helps to reduce the possible biases of the model. A third advantage is that issues of under-estimation (Auffhammer and Carson, 2008) can be addressed by running panel regression. This property can result in revealing dynamics that is difficult to detect with cross-sectional data (Doughtery, 2011).

[43] The time period for Germany's data was from 1992 to 2009 because this interval was the period after the unification of East and West Germany.

The following details the steps that are taken for panel regression for the selected OECD economies as well as the accompanying findings:

STEPS

i. The ratios for the variables of macroeconomic goals (π, N, GDP) and an economy's steady state ratios [(k^* / k), (k^{**} / k)], as shown in Table 6.2 were calculated for all of the 11 selected OECD economies for the observed years from 1980 to 2009
ii. The OECD economies were then grouped geographically into five groups. The groups are ASIA (Japan and Korea), PACIFIC (Australia and New Zealand), AMERICAS (Canada, Mexico, and the USA), EUROPE1[44] (France and Germany), and EUROPE2 (Norway and the United Kingdom)
iii. Each group was subjected to a panel regression application to determine a general equation for each of the macroeconomic goals. Based on a 20%[45] level of significance, stepwise regression was applied to filter the independent non-significant variables, in a continuing process until all variables in the equations were significant

[44] Europe is grouped into Europe1 and Europe2 because of similarities in the economies' economic constituents.
[45] The level of significance was set at 20% because this value was the threshold level for the majority of the tested variables to be significant.

FINDINGS

The PACIFIC, AMERICAS and EUROPE1 groups were explained well by the panel regression results. The equations generated for each of the macroeconomic variables were applied for each of the economies in the specific group. Note also that the employment equations generated for Australia by panel regression failed to satisfy the 20% level of significance. Hence, linear regression was used to generate the equations for employment and the steady state ratio for Australia.

Panel regression analysis failed to generate satisfactory outcomes for both ASIA and EUROPE2 groups. Linear regression was considered a suitable alternative for deriving a relationship between macroeconomic variables and steady state. To generate equations for each of the macroeconomic variables for ASIA, linear regression was performed for both the Japanese and Korean economies (notwithstanding that there could be an underestimation with using regression results). Panel regression analysis also failed to produce significant results for the EUROPE2 group, Norway and the United Kingdom. Similar to Japan and Korea, linear regression analysis was performed for Norway and the United Kingdom. However, regression results for Norway was not significant and hence, Norway was rejected.

The main objective of this analysis is two folds. First, a relationship is sought between the macroeconomic variables and the steady state ratio. Second, is to observe the trends between each macroeconomic variable with respect to the economy's steady state ratio as well as the different outcomes when the same analysis is made for the standard macroeconomic model and the EM model. Please refer to Appendix 6.1 for all of the STATA Regression outputs.

RESULTS

The results of the regressions are presented in Appendix 6.2. Table 6.5 shows the general regression equations for Japan, Korea, and the United Kingdom. And Table 6.6 shows the general panel regression equations for Australia, New Zealand, Canada, Mexico, the USA, France and Germany.

The equations in Tables 6.5 and 6.6 can be simplified to produce a direct causal relationship between the macroeconomic variables and the steady state ratio of the economy for the year 2009. This result is accomplished by making the macroeconomic variable/s on the right hand side of the equation constant. In other words, the variables are substituted with 2009 values. The resulting equations *(in italics)* which relate the macroeconomic variables to the steady state ratios of an economy are presented in Tables 6.7 to 6.11 in Appendix 6.2.

4. 2009 SNAPSHOT OF STANDARD MACROECONOMICS FRAMEWORK VERSUS ENVIRONMENTAL-MACROECONOMICS (EM) FRAMEWORK

The equations for the three macroeconomic variables of each economy are plotted to obtain an explanatory relationship with respect to the steady state ratios of the economy for the Year 2009. Note that the Year 2009 was selected as it had the latest and complete set of required data at time of study. However, 2009 was the immediate year after the 2008 Global Financial Crisis (GFC). There is a possibility that this analysis could have been skewed as a result of the GFC exogenous shock. The graphs for each of the economies are presented in Appendix 6.3.

There are three economies (Australia, Canada, and the United Kingdom) with macroeconomic variables that display a significant disparity in the explanatory relationship when the standard macroeconomic and the EM model are applied. These graphs are presented below in Figure 6.2 to 6.5.

Australia – Inflation (π)

$\mathrm{Ln}(\pi) = 0.067 + 0.017 \ln(k^{*} / k)$, $\mathrm{Ln}(\pi) = 0.079 + 0.026 \ln(k^{**} / k)$

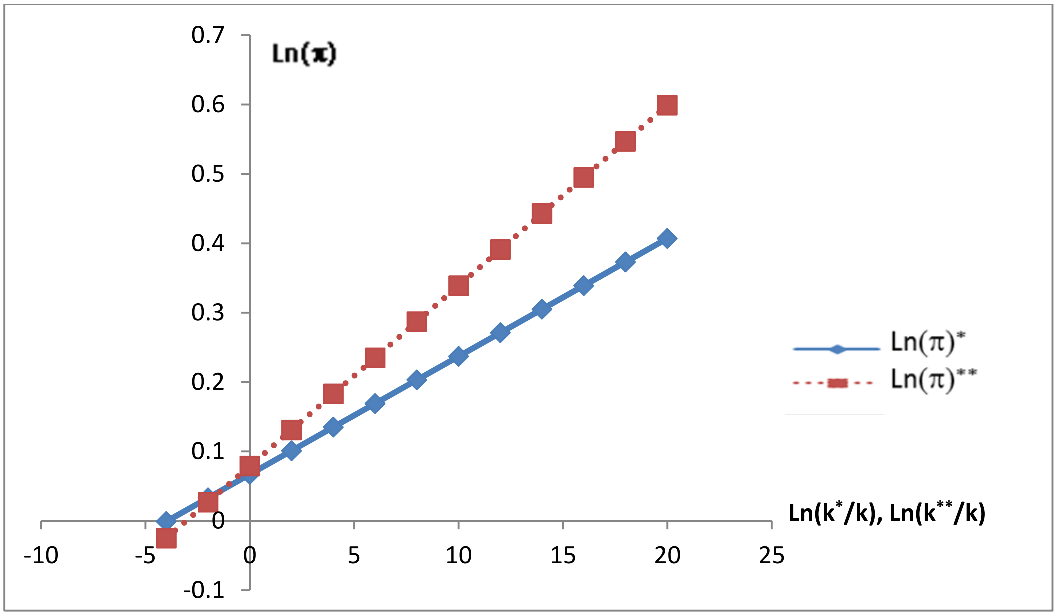


Figure 6.2: Australia's Inflation and Steady State Ratio

Australia – Employment

$Ln(Employment) = 0.004 + 0.0317ln(k^{*} / k)$,$Ln(Employment) = 0.009 + 0.0309\ ln(k^{**} / k)$

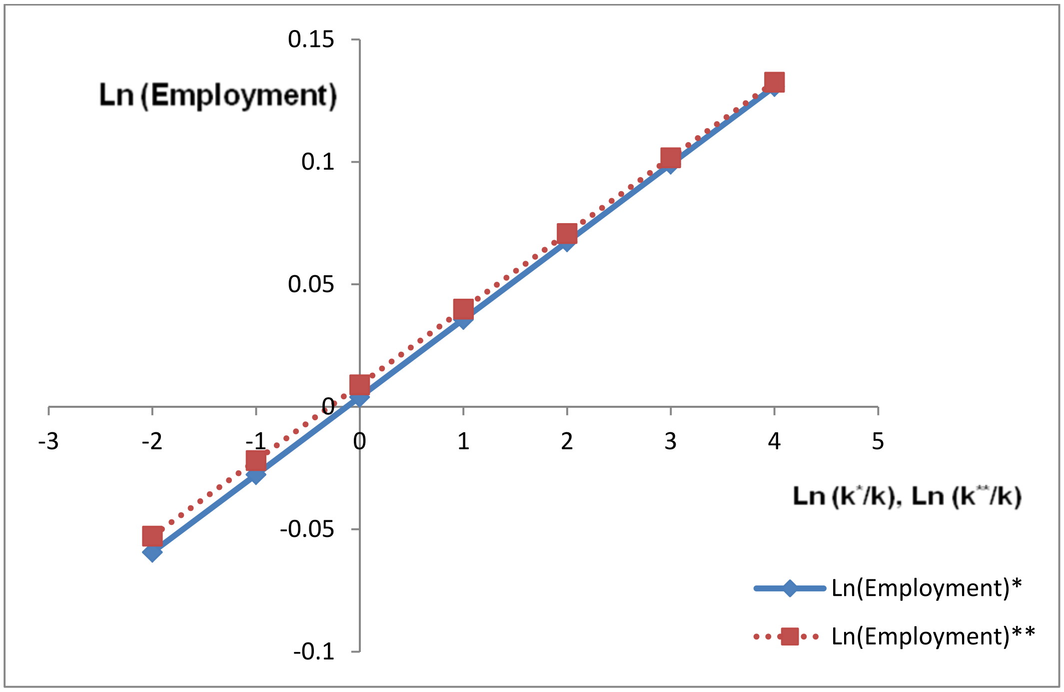


Figure 6.3: Australia's Employment and Steady State Ratio

<u>Canada – Inflation (π)</u>

$\text{Ln}(\pi) = 0.192 - 0.025\ \ln(k^{*} / k)$, $\text{Ln}(\pi) = 0.191 - 0.014\ \ln(k^{**} / k)$

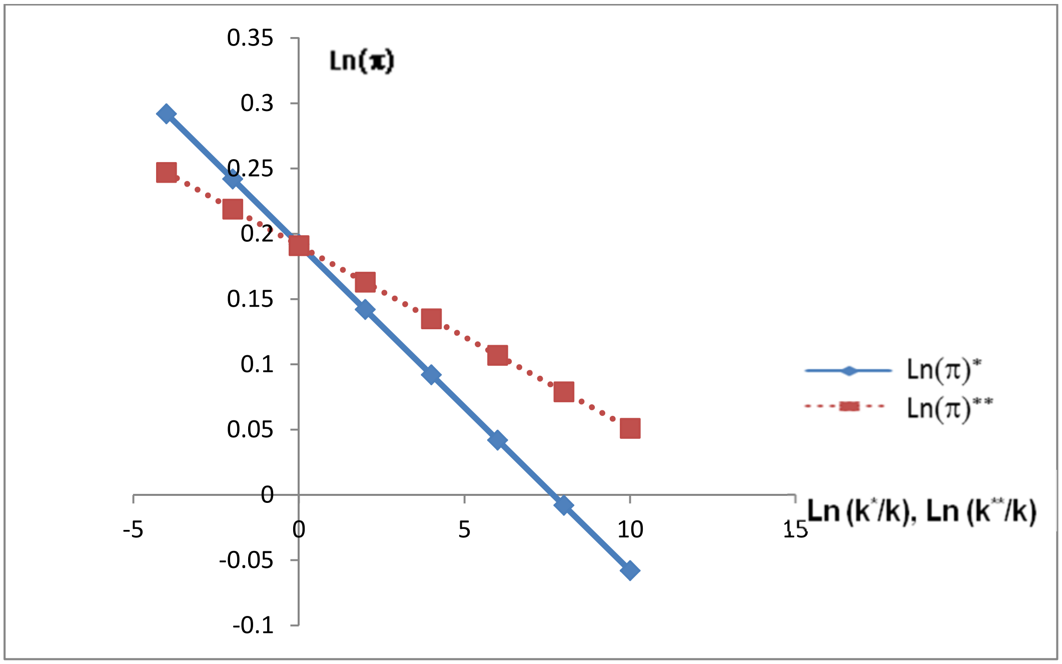


Figure 6.4: Canada's Inflation and Steady State Ratio

United Kingdom – Employment

$\text{Ln(Employment)} = 0.047 - 0.063 \ln(k^{*} / k)$, $\text{Ln(Employment)} = -0.021 - 0.053 \ln(k^{**}/k)$

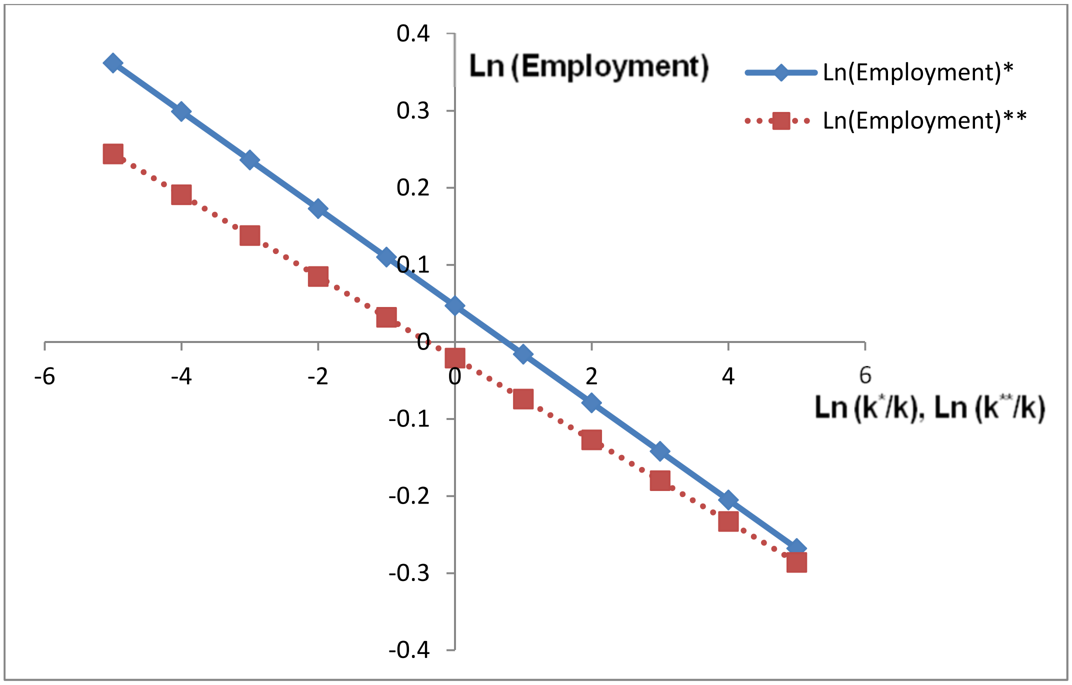


Figure 6.5: United Kingdom's Employment and Steady State Ratio

The four graphs presented above will be analysed further in Chapter Seven.

Table 6.4 summarises the relationship for the macroeconomic variables and the steady state ratios of the respective economies.

Economies (For the Year 2009)	**π: f [ln (k^* / k), ln (k^{**} / k)]**	**N : f [ln (k^* / k), ln (k^{**} / k)]**	**Per Capita GDP: f [ln (k^* / k), ln (k^{**} / k)]**
Group A			
Below Capacity, (k^* / k) > 1			
Canada	Negative Relationship	Negative Relationship	Positive Relationship
France	Positive Relationship	Positive Relationship	Positive Relationship
Korea (regression)	Positive Relationship	Positive Relationship	Positive Relationship
Beyond Capacity, (k^{**} / k) < 1			
Canada	Negative Relationship	Negative Relationship	Positive Relationship
France	Positive Relationship	Positive Relationship	Positive Relationship
Korea (regression)	Positive Relationship	Positive Relationship	Positive Relationship
Group B			
B: Beyond Capacity, (k^* / k) or (k^{**} / k) < 1			
Australia	Positive Relationship	Positive Relationship	Positive Relationship
Germany	Positive Relationship	Positive Relationship	Positive Relationship
Japan (regression)	Positive Relationship	Positive Relationship	Negative Relationship
Mexico	Negative Relationship	Negative Relationship	Positive Relationship
New Zealand	Positive Relationship	Positive Relationship	Positive Relationship
UK (regression)	Positive Relationship	Negative Relationship	Positive Relationship
USA	Negative Relationship	Negative Relationship	Positive Relationship

Table 6.4: Nature of the Relationship of Macroeconomic Variables with [(k^*/k), (k^{**}/k)]

5. FINDINGS AND ANALYSIS OF THE 2009 SNAPSHOT BETWEEN MACROECONOMIC VARIABLES AND THE CAPACITY OF AN ECONOMY

There are four main findings from the graphical representation and the results in Table 6.4.

i. The status of the selected economies with respect to the SSE changes when KN is internalised. In other words, an economy moves from below the SSE to beyond the SSE. This is illustrated in Figure 6.6. An economy is at k with a steady state ratio at (k^* / k) in the standard model. When KN is internalised in the EM model, an economy's steady state ratio shifts leftwards to (k^{**} / k), at which a lower level of income Y^{**} is observed. Here, (k^{**} / k) is reached sooner in the EM model compared to the standard macroeconomic model.

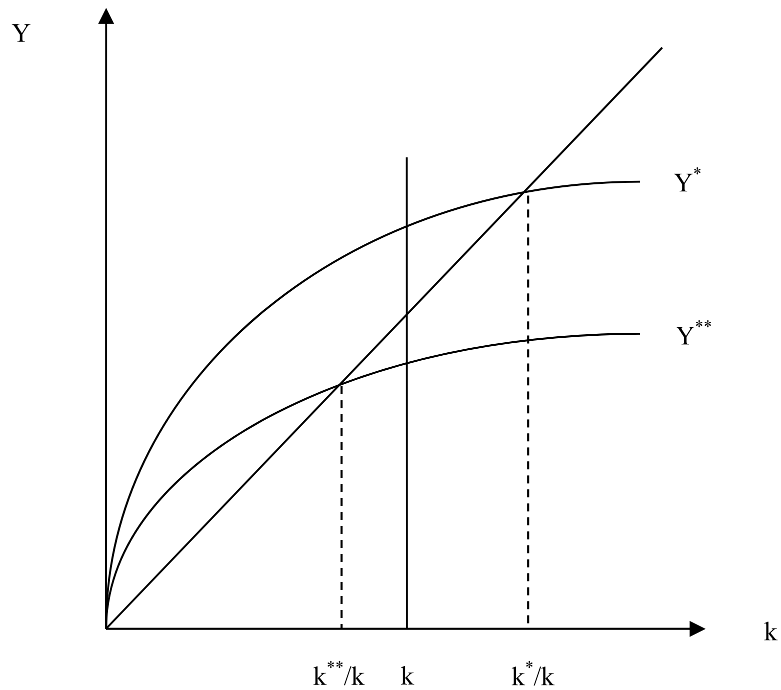


Figure 6.6: Economy Moving from Below the Steady State Equilibrium to Beyond the Steady State Equilibrium when Environmental Capital is Internalised

This relationship is true for the economies in Group A (Canada, France and Korea); these economies move from below capacity to beyond capacity when KN is internalised in the EM model. The fact that there are two different states of capacity in two different models suggests a policy error for the selected economies in Group A. The capacity of the economies is exacerbated by the standard macroeconomic model.

ii. Economies that are beyond the SSE have the extent of exceedance of capital per labour (KM / L) increased, when KN is internalised in the EM model, with plausibility of the exceedance having an impact on the steady state ratio of an economy. This is illustrated in Figure 6.7, in which the steady state ratio of the EM model is significantly below that of the standard macroeconomic model.

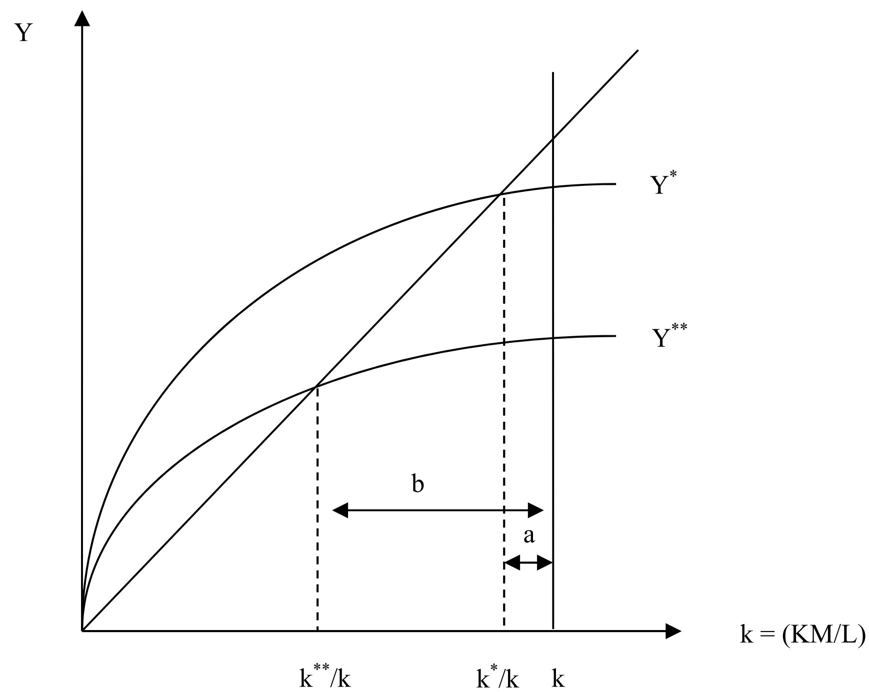


Figure 6.7: Economies Operating Beyond the Steady State Equilibrium with Significant Exceedance Observed

This relationship is evident in the economies in Group B (Australia, Germany, Japan, Mexico, New Zealand, UK and the USA), for which an increase in the extent of exceedance is observed when KN is internalised in the EM model.

iii. The nature of the relationship between the macroeconomic variables and steady state ratios [(k^* / k), (k^{**} / k)] is the same across both the standard macroeconomic model and the EM model.

In other words, the positive or negative relationship demonstrated by π, N, and per capita GDP with respect to (k^* / k) and (k^{**} / k) remain unchanged be it the standard macroeconomic model or the EM model.

iv. The functional forms derived do not display similarity in terms of the groupings based on whether an economy is operating within or beyond capacity. In accordance with expectations, the similarities are in terms of the panel groupings based on the geographic considerations discussed earlier.

There are five economies, namely Australia, Germany, New Zealand, France and Korea for which all of the variables that describe the macroeconomic goals show a positive relationship. While all these economies are operating at beyond capacity, France and Korea are the only ones operating beyond capacity with the EM model.

The remaining five economies, Canada, Japan, Mexico, the UK and the USA, show a mixed relationship. For these economies, all of the macroeconomic variables do not show a consistent positive or negative relationship. Both the standard macroeconomic and the EM models display similar relationships among the macroeconomic variables for all of the economies. The EM model is not the source of this discrepancy. Hence, there could be other factors that result from institutional, social or political constraints.

6. CONCLUSION

Panel regression was used to provide an explanatory relationship between the macroeconomic goals and the SSE for the economies of Australia, Canada, France, Germany, Mexico, New Zealand, and the USA. However, there are some economies for which panel regression failed to provide a conclusive finding. A linear regression was used (instead of panel regression) to explain the relationships for the economies of Japan, Korea, and the United Kingdom. However, the type of regression used to determine such relationships between macroeconomic goals and the SSE appears to be inconsequential, based on the observation that there exist two different steady states in two different models, namely, the standard macroeconomic and the EM models. This observation plainly suggests the existence of a policy error for the selected economies exhibiting such phenomenon. In addition, the strength of the relationships was different across the two different models for selected macroeconomic variables. These results are sufficient grounds to argue that the policy ranges presented to policy makers for policy making were incorrect based on the standard macroeconomic model. Instead, the EM model should be used so that flawed policy decisions can be avoided. The next chapter will present some significant findings that evolved from this analysis made.

Chapter Seven – Policy Ranges Analysis – Some Significant Findings

1. INTRODUCTION

It was established in Chapter Five that the standard macroeconomic model overstates the steady state equilibrium (SSE) of an economy; in other words, the capacity of an economy might not be represented correctly (Chapter Six). The focus of this chapter is to illustrate the different policy ranges for the three OECD economies highlighted in Chapter Six. The policy range would of course differ between the standard macroeconomic model and the environmental-macroeconomics (EM) model. The contention here is that the standard macroeconomic model provides a mistaken policy range. Furthermore, should policy recommendations be made based on a mistaken domain, the proposed policy might not be effective in achieving the desired outcome.

The chapter will start with an illustration on the relationship between selected macroeconomic variables and the ratio of steady state capital per worker to observed capital per worker [(k^{*} / k), (k^{**} / k)]. This will be followed by a case illustration of Australia and conclusion.

The economies chosen for this illustration are Australia, Canada, and the United Kingdom (UK). As highlighted in Chapter Six, these economies displayed significant differences when the steady state outcomes of the EM model were compared with those of the standard macroeconomic model. The selected macroeconomic variables are inflation (π) and employment (N). In other words, the following relationships are illustrated through panel and linear regressions:

$\{\pi = f(k^{*} / k); \pi = F(k^{**} / k)\}; \{N = g(k^{*} / k); N = G(k^{**} / k)\}$

The context of illustration is that of the year 2009, in which intervention was sought for stabilisation with targeted values and for considering how changes in $[(k^{*} / k), (k^{**} / k)]$ could lead to desired policy outcomes with reference to inflation and employment.

A note of caution is in order. As shown the key variables do not display satisfactory levels of significance in some cases, for example, Canada's inflation. Therefore, the relationships are primarily intended to illustrate the distinction between the standard macroeconomic model and the EM model; as well as the intensity of the changes of the variables between the standard macroeconomic model and the EM model.

2. ANALYSIS OF DIFFERENT POLICY RANGES: INFLATION

Inflation (π) and the steady state ratios $[(k^{*} / k), (k^{**} / k)]$

The panel regression outputs for Canada and Australia are presented below in Tables 7.1 and 7.2 respectively:

Canada’s Inflation				
Variable	**Coefficient**	**Robust *s.e.***	***p*-value**	$\mathbf{R^2}$
Constant	0.2428	0.0478	0.000	0.3921
$\mathbf{Ln(k^* / k)}$	-0.0252	0.0338	0.455	
Ln(GDP Ratio)	-10.26	2.554	0.000	
Equation	$Ln(\pi) = 0.192 – 0.025 \ln(k^* / k)$ (7.1)			
Variable	**Coefficient**	**Robust *s.e.***	***p*-value**	$\mathbf{R^2}$
Constant	0.2432	0.0514	0.000	0.3904
$\mathbf{Ln(k^{**} / k)}$	-0.0139	0.0309	0.653	
Ln(GDP Ratio)	-10.41	2.534	0.000	
Equation (EM)	$Ln(\pi) = 0.191 – 0.014 \ln(k^{**} / k)$ (7.2)			

Table 7.1: Standard Macroeconomic (*) and EM (**) Model Regression Output for Canada’s Inflation for the Year 2009

Australia's Inflation				
Variable	**Coefficient**	**Robust *s.e.***	***p*-value**	**R^2**
Constant	0.0764	0.0169	0.000	0.3128
$Ln(k^* / k)$	0.0168	0.0159	0.291	
Ln(Employment)	0.4646	0.1073	0.000	
Ln(GDP Ratio)	-2.111	0.7125	0.003	
Equation	$Ln(\pi) = 0.067 + 0.017 \ln(k^* / k)$ (7.3)			
Variable	**Coefficient**	**Robust *s.e.***	***p*-value**	**R^2**
Constant	0.0880	0.0152	0.000	0.3688
$Ln(k^{**} / k)$	0.0261	0.0102	0.011	
Ln(Employment)	0.4305	0.1102	0.000	
Ln(GDP Ratio)	-2.138	0.6169	0.001	
Equation (EM)	$Ln(\pi) = 0.079 + 0.026 \ln(k^{**} / k)$ (7.4)			

Table 7.2: Standard Macroeconomic (*) and EM (**) Model Regression Output for Australia's Inflation for the Year 2009

Note that as indicated in Chapter Six, $\ln(\pi)$ denotes the natural log value of a given year's deflator divided by the previous year's deflator (see Table 6.2).

The low R^2 values observed clearly limit the predictive capability of the models. Nevertheless, some important observations can be made.

1. The nature of the relationship is the opposite in Canada compared to that of Australia. The relationship in the case of Canada is inverse implying that increasing $[(k^* / k), (k^{**} / k)]$ will reduce inflation. In the case of Australia, this relationship is positive. In other words, increasing $[(k^* / k), (k^{**} / k)]$ will increase inflation.

2. However, in both cases, it is possible to show that the environmental capital (KN) is a driver of inflation and that the inflation policy range with the EM model is larger compared to the standard macroeconomic model.

Consider first the case of Canada. The inflation target set by the Bank of Canada is 2 per cent[46]. In terms of the ratio of deflators used in the model, this target inflation rate amounts to ln(1.02) = 0.0198. Table 7.3 below illustrates the policy range in terms of the predicted values of inflation from the model and the targeted values for Canada.

[46] According to the Bank of Canada, the inflation-control target was adopted in 1991 and has been renewed five times since then, most recently in November 2011 for the five years to the end of 2016. The target aims to maintain the total CPI inflation at the 2 per cent midpoint of a target range of 1 to 3 per cent over the medium term. The Bank raises or lowers its policy interest rate, as appropriate to achieve the target *typically* within a horizon of six to eight quarters—the time that it usually takes for policy actions to work their way through the economy and have their full effect on inflation. http://www.bankofcanada.ca/rates/indicators/key-variables/inflation-control-target/#targetrange

Ln(π)	**Standard Model**	**EM Model**
Ln(π)$_{Predicted}$	0.1887	0.1915
Ln(π)$_{Targeted}$	0.0198	0.0198
Policy Range Gap	0.1692	0.1717

Table 7.3: Values of ln(π)$_{Predicted}$ and ln(π)$_{Targeted}$ and the Policy Range Gap for Canada

There is a clear disparity between the predicted and targeted values of inflation for the Canadian economy. In spite of the poor predictive capability of the model, it is evident that the policy range elicited from the EM framework is larger relative to the standard macroeconomic framework. In line with the illustration provided graphically in Figure 7.1, the policy analyst who relies on the standard macroeconomic model would explore avenues for reducing ln(π) from 0.1887 to 0.0198 (solid curve). However, in terms of the EM model, such avenues would have to be explored over a larger range from 0.1915 to 0.0198 (dotted curve).

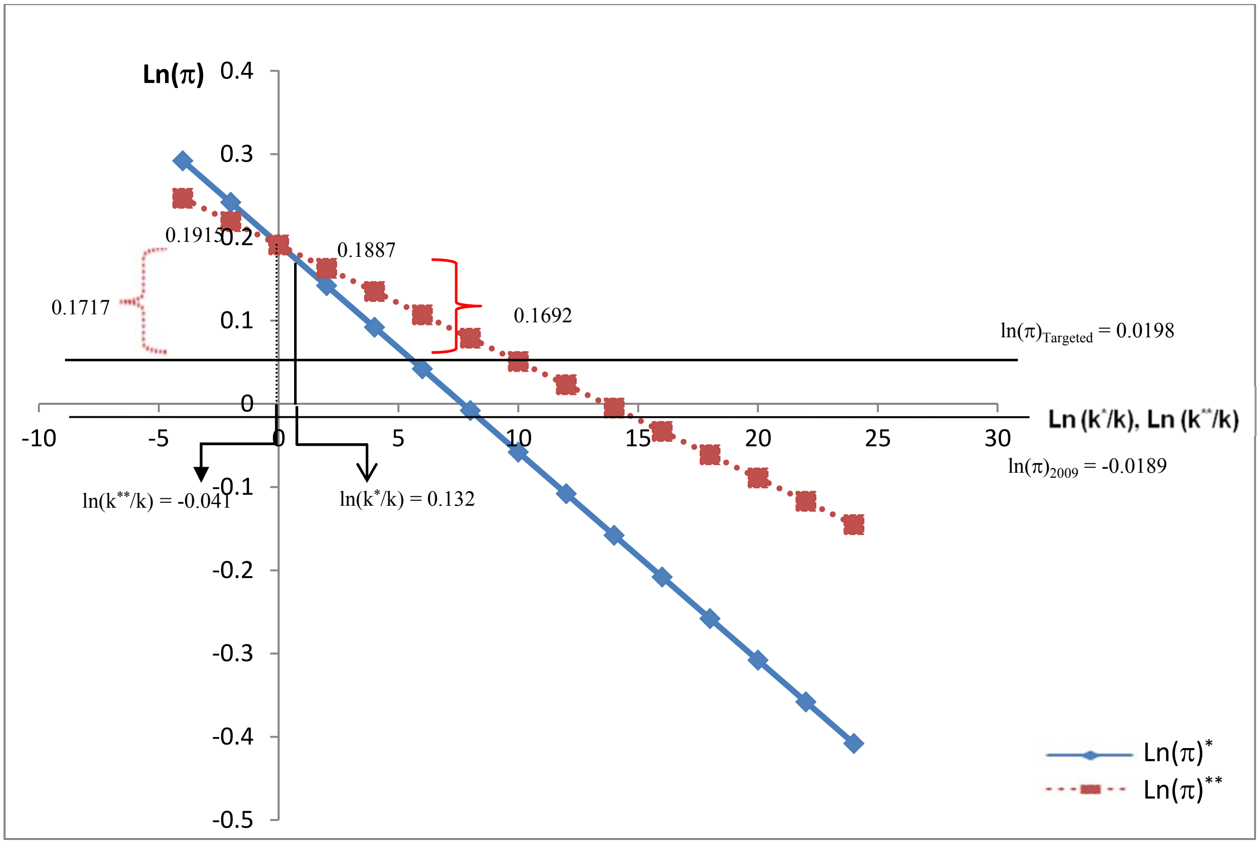


Figure 7.1: Canada's Inflation Policy Range for the

Standard Macroeconomic (*) and EM (**) Models for the Year 2009

Furthermore, it is also evident that in the Canadian context, the gradient of the relationship is smaller with the EM model than that of the standard macroeconomic model (see equations (7.1) and (7.2)). In other words,

$$\{\delta[\ln(\pi)] / \delta[\ln(k^* / k)]\} > \{\delta[\ln(\pi)] / \delta[\ln(k^{**} / k)]\}$$

This difference in the gradient shows that there is a larger resistance for inflation to fall when the ratio (k^{**} / k) is raised with the EM model than with (k^* / k) in the standard macroeconomic model. In other words, (k^{**} / k) must be raised by almost twice the amount of (k^* / k) to bring inflation down to the targeted level. Hence, it is possible to postulate that KN is a driver of inflation. In terms of raising the steady state ratios [(k^* / k), (k^{**} / k)] for achieving the desired inflation level, it is evident that the required increase of (k^{**} / k) is greater than that required of (k^* / k).

This scenario means that, in terms of the standard macroeconomic model, the observed k is within the SSE ($k^* > k$) whilst in terms of the EM model, the Canada's observed capital stock (k) exceeds the SSE ($k > k^{**}$). According to the model outcomes presented above for Canada, the ratios [(k^* / k), (k^{**} / k)] need to be increased to reduce the level of inflation. The observed 2009 values of ln(k^* / k) and ln(k^{**} / k) are, respectively, 0.132 and -0.041. To increase these ratios, the level of k needs to be reduced. Alternatively, k^* and k^{**} can also be increased to increase both ratios. This increase can be achieved by means of increasing the factor productivity of capital, which can create capacity for the Canadian economy.

Consider now the case of Australia. The inflation target set by the Reserve Bank of Australia is 2.5 per cent[47]. In natural log terms, the inflation target is ln(1.025) = 0.0247. Similar to the Canadian case, the policy range with the EM model is larger than that with the standard macroeconomic model. This relationship occurs in spite of the opposite nature of the relationship in the Australia model. Table 7.4 below illustrates the policy

[47] According to the Reserve Bank of Australia (RBA), the appropriate target for monetary policy in Australia is to achieve an inflation rate of 2 to 3 per cent, on average over the cycle as agreed by the Governor and the Treasurer. If inflation was to follow the RBA's target of 2 to 3 per cent, then let's assume the mid-range of 2.5 per cent. http://www.rba.gov.au/inflation/inflation-target.html

range in terms of the predicted values of inflation given by the two models and the targeted values for Australia.

Ln(π)	**Standard Model**	**EM Model**
$Ln(\pi)_{Predicted}$	0.0665	0.0748
$Ln(\pi)_{Targeted}$	0.0247	0.0247
Policy Range Gap	0.0418	0.0501

Table 7.4: Values of $\ln(\pi)_{Predicted}$ and $\ln(\pi)_{Desired}$ and the Policy Range Gap for Australia

Additionally, it can be noted that the gradient of the relationship with the EM model is steeper than that of the standard macroeconomic model. This is the reverse of what was observed for Canada (see equations (7.3) and (7.4)) which implies that raising the ratios $[(k^* / k), (k^{**} / k)]$ by the same amount will result in a smaller increase in the inflation outcomes with the EM model compared to the standard macroeconomic model. These relationships are illustrated graphically below in Figure 7.2.

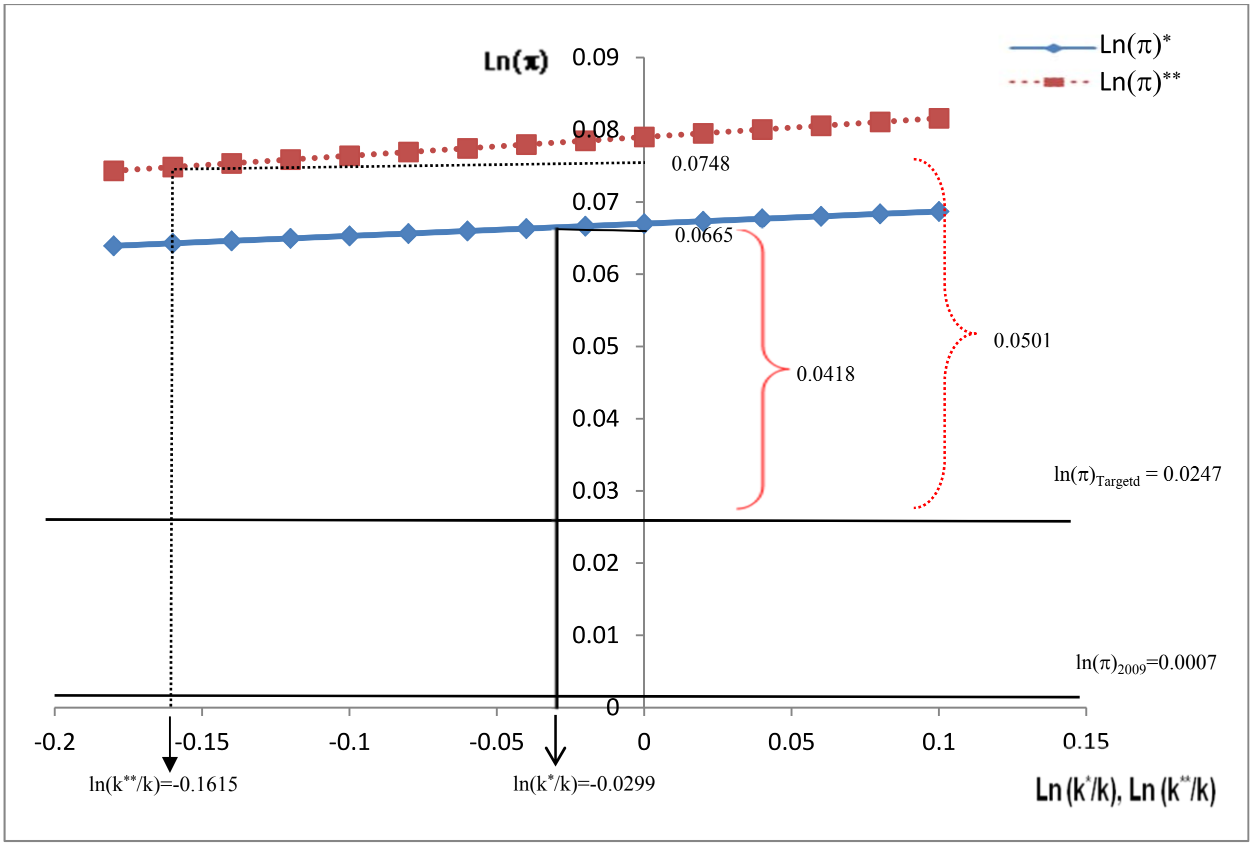


Figure 7.2: Australia's Inflation Policy Range for the

Standard Macroeconomic (*) and EM (**) Models for the Year 2009

As indicated above for the Canadian case, a given increase in the ratios [(k^* / k), (k^{**} / k)] results in a smaller decline in inflation with the EM model than with the standard macroeconomic model. Hence, in both cases (Canada and Australia), the presence of KN is seen to magnify the extent of inflation by reducing it at a slower rate (the Canadian case) or by increasing it at a faster rate (the Australian case). Given that the regression results for Australia proved to be a poor predictor of the observed inflation level compared to that of Canada, it is difficult to suggest means of achieving the desired inflation targets through changes in the ratios [(k^{*} / k), (k^{**} / k)]. If such changes were to be pursued, significant reductions in $\ln(k^{*} / k)$ and $\ln(k^{**} / k)$ would have to be achieved.

3. ANALYSIS OF DIFFERENT POLICY RANGES: EMPLOYMENT

Employment and the steady state ratios [(k^{*} / k), (k^{**} / k)]

The linear regression outputs for UK and Australia are presented below in Tables 7.5 and 7.6 respectively:

UK's Employment				
Variable	**Coefficient**	**Robust *s.e.***	***p*-value**	R^2
Constant	-0.0297	0.0117	0.017	0.3807
$Ln(k^* / k)$	-0.0633	0.0259	0.021	
$Ln(\pi)$	0.1906	0.0907	0.045	
Ln(GDP Ratio)	1.779	0.4332	0.000	
Equation	$Ln(Employment) = 0.047 – 0.063\ ln(k^* / k)$ (7.5)			
Variable	**Coefficient**	**Robust *s.e.***	***p*-value**	R^2
Constant	-0.0364	0.0130	0.010	0.3338
$Ln(k^{**} / k)$	-0.0526	0.0341	0.135	
$Ln(\pi)$	0.1288	0.0941	0.183	
Ln(GDP Ratio)	1.649	0.4405	0.001	
Equation (EM)	$Ln(Employment) = -0.021 – 0.053\ ln(k^{**}/k)$ (7.6)			

Table 7.5: Standard Macroeconomic (*) and EM (**) Model Regression Output for the UK's Employment for the Year 2009

Australia's Employment				
Variable	**Coefficient**	**Robust *s.e.***	***p*-value**	$\mathbf{R^2}$
Constant	-0.0014	0.0087	0.876	0.1954
$\mathbf{Ln(k^* / k)}$	0.0317	0.0178	0.086	
$\mathbf{Ln(\pi)}$	0.3084	0.1177	0.014	
Ln(GDP Ratio)	0.9088	0.4057	0.034	
Equation	$Ln(Employment) = 0.004 + 0.0317ln(k^*/k)$ (7.7)			
Variable	**Coefficient**	**Robust *s.e.***	***p*-value**	$\mathbf{R^2}$
Constant	0.0036	0.0075	0.633	0.2142
$\mathbf{Ln(k^{**} / k)}$	0.0309	0.0153	0.054	
$\mathbf{Ln(\pi)}$	0.2874	0.1093	0.014	
Ln(GDP Ratio)	0.9440	0.4058	0.028	
Equation (EM)	$Ln(Employment) = 0.009 + 0.0309\ ln(k^{**}/k)$ (7.8)			

Table 7.6: Standard Macroeconomic (*) and EM (**) Model Regression Output for Australia's Employment for the Year 2009

Note that as indicated in Chapter Six, ln(Employment) denotes the natural log value of a given year's employment divided by the previous year's employment (see Table 6.2).

Similar to the macroeconomic variable inflation, the low R^2 values and high p-values of the constant observed for Australia clearly limit the predictive capability of the models. Nevertheless, some important observations can be made.

1. The nature of the relationship is the opposite in the UK compared to that of Australia. The relationship in the case of the UK is the inverse, which implies that increasing the steady state capacity ratio will reduce employment. In the case of Australia, this relationship is positive. In other words, increasing the steady state capacity ratio will increase employment. Therefore, the environmental capital (KN) exercises some influence on employment for Australia.

2. In both the UK and Australia, the employment policy range is smaller with the EM model compared to the standard macroeconomic model.

Comparing the macroeconomic variables of inflation and employment, inflation can be targeted but employment is not as straightforward. This is because rather than trying to attain full employment, Friedman (1968) argues that policy makers should try to keep prices stable (at a low or even zero inflation rate). If such a policy is sustained, then Friedman suggests that the economy will gravitate to full employment, which is the "natural" rate of unemployment automatically. However, herein, employment is studied as a discrete variable without coupling it with inflation.

Consider first the case of UK. Table 7.7 below presents a comparison of the predicted and actual values of ln(Employment).

$\ln(k^* / k)$, $\ln(k^{**} / k)$	ln(Employment)	Actual ln(Employment)
$\ln(k^* / k) = 0.022$	ln(Employment) = 0.0456	-0.0210
$\ln(k^{**} / k) = -0.115$	ln(Employment) = -0.0149	

Table 7.7: Comparison of the Predicted ln(Employment) versus the Actual ln(Employment) – UK

The predicted value of ln(Employment) for the standard macroeconomic model is very different from the actual 2009 value of ln(Employment). However, the predicted value of ln(Employment) [-0.0149] for the EM model is reasonably close to the actual 2009 value of ln(Employment) [-0.0210]. This difference can be attributed to the R^2 value of 0.3338 for the EM model which is illustrated graphically below in Figure 7.3.

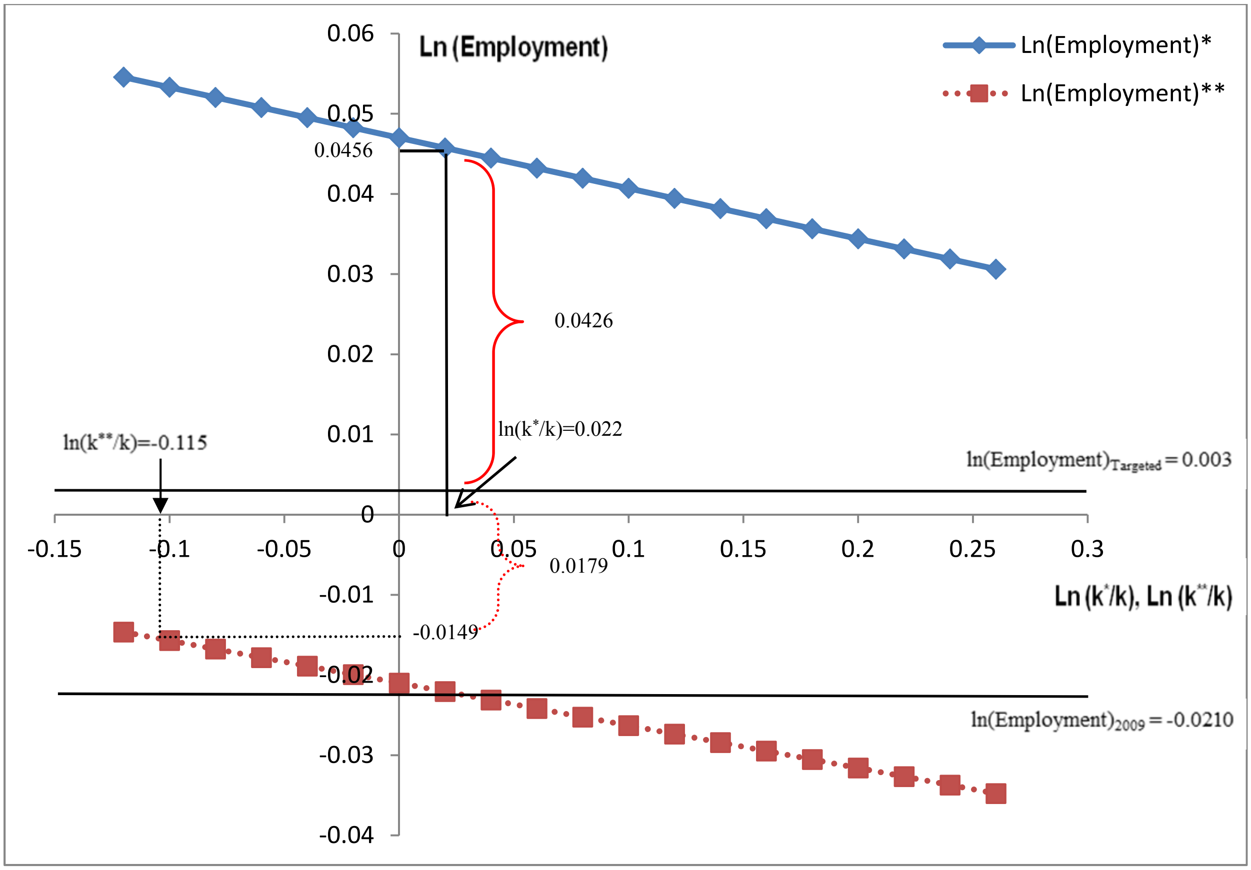


Figure 7.3: UK's Employment Policy Range for the

Standard Macroeconomic (*) and EM (**) models for the Year 2009

Furthermore, it is also evident that the gradient of the relationship is smaller for the EM model than that for the standard macroeconomic model (see equations (7.5) and (7.6)). In other words,

$$\{\delta[\ln(\text{Employment})] / \delta[\ln(k^* / k)]\} > \{\delta[\ln(\text{Employment})] / \delta[\ln(k^{**} / k)]\}$$

This difference in the gradient shows that there is a greater resistance for employment to fall when the steady state ratio is raised with the EM model than with the standard macroeconomic model.

Assume that the targeted level of UK employment is to rise by 0.3 per cent; then, the employment ratio would be 1.003. In other words, ln(Employment) is 0.003. Table 7.8 below illustrates the policy range in terms of the predicted and targeted ln(Employment) for the UK.

Ln(Employment)	**Standard Model**	**EM Model**
$Ln(Employment)_{Predicted}$	0.0456	-0.0149
$Ln(Employment)_{Targeted}$	0.003	0.003
Policy Range Gap	0.0426	0.0179

Table 7.8: Values of $ln(Employment)_{Predicted}$ and $ln(Employment)_{Targeted}$ and the Policy Range Gap for the UK

It is clear that there is a huge disparity between the predicted and targeted values of employment for the UK economy based on the standard macroeconomic model and the EM model. As a result, it is evident that the policy range elicited from the EM framework is smaller than that of the standard macroeconomic model, a relationship that was illustrated graphically above in Figure 7.3.

What is required in the UK context (at least according to the model outcomes presented here) is for (k^* / k) and (k^{**} / k) to contract for achieving higher employment outcomes. Note that the observed 2009 values of $\ln(k^* / k)$ and $\ln(k^{**} / k)$ are respectively 0.022 and -0.115. In terms of the EM model, the UK's observed capital stock (k) exceeds the SSE whilst in terms of the standard macroeconomic model, the observed k is within the SSE.

If one were to abide by the standard macroeconomic model, then the implications of using equation (7.5) toward increasing employment would be to increase k so that (k^* / k) would decrease and hence, employment could increase. However, in terms of the EM model, one must reduce k because (k > k^{**}). This reduction would raise (k^{**} / k) and reduce employment. Thus, in the first instance, one must explore ways of increasing k^{**}. This would influence the search for technological advancements that would shift the production function [Y = g (KM, L, KN)] upward. The intention is to create capacity for an economy, and raising (k^{**} / k) would increase employment as per equation (7.6). These considerations illustrate the significantly different policy approaches that unfold in terms of the two models.

Consider now the case of Australia. Table 7.9 below presents a comparison of the predicted and actual values of ln(Employment).

ln(k^* / k), ln(k^{**} / k)	**ln(Employment)**	**Actual ln(Employment)**
ln(k^* / k) = -0.0299	ln(Employment) = 0.0031	0.0033
ln(k^{**} / k) = -0.1615	ln(Employment) = 0.0040	

Table 7.9: Comparison of the Predicted ln(Employment)
versus the Actual ln(Employment) – Australia

The predicted values of ln(Employment) for both the standard macroeconomic and EM models are close to the actual 2009 value of ln(Employment). This similarity holds even though the R^2 values for both models are low which is illustrated graphically below in Figure 7.4.

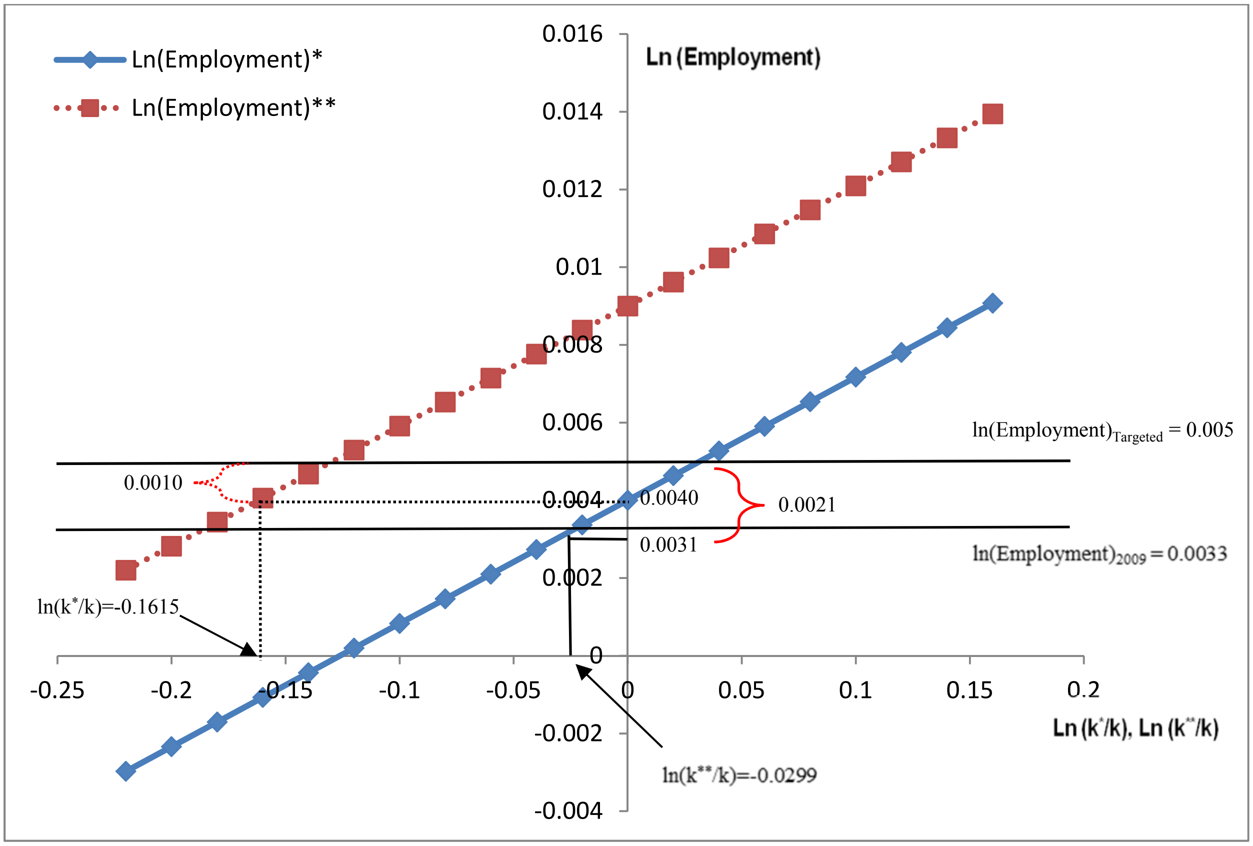


Figure 7.4: Australia's Employment Policy Range for
the Standard Macroeconomic (*) and EM (**) Models for the Year 2009

Assume that the targeted level of Australia's employment is to rise by 0.5 per cent. Then the employment ratio would be 1.005. In other words, ln(Employment) is 0.005. The policy range with the EM model is half that for the standard macroeconomic model. Table 7.10 below illustrates the policy range in terms of the predicted values of employment from the model and the targeted values for Australia.

Ln(Employment)	Standard Model	EM Model
$Ln(Employment)_{Predicted}$	0.0031	0.0040
$Ln(Employment)_{Targeted}$	0.005	0.005
Policy Range Gap	0.0021	0.0010

Table 7.10: Values of $ln(Employment)_{Predicted}$ and $ln(Employment)_{Targeted}$ and the Policy Range Gap for Australia

In contrast to the UK context, with the case of Australia, increases in (k^* / k) and (k^{**} / k) are required for achieving higher levels of employment. However, the observed 2009 values of k^* and k^{**} are less than k. The result is negative log values for (k^* / k) and (k^{**} / k): -0.0299 and -0.1615 which implies that raising (k^* / k) and (k^{**} / k) must be achieved by either decreasing k or increasing k^* or k^{**}. Given that the contraction of k is difficult to achieve, increasing k^* or k^{**} would seem to be more relevant. This increase would involve raising the productivity of k.

4. THE CASE OF AUSTRALIA – POLICIES TO ADDRESS THE GAPS

There is one interesting observation for Australia in the macroeconomic variables of inflation and employment. To reduce inflation, one must reduce the steady state ratios [(k^* / k), (k^{**} / k)]. However, to increase employment, one must increase the steady state ratios [(k^* / k), (k^{**} / k)]. There is a trade-off between inflation and employment in the Australia case. Increasing the ratios [(k^* / k), (k^{**} / k)] increases employment, but this change will also increase inflation. Thus, the trade-off for increased employment is higher inflation.

The unique reliance on China and a huge demand for natural resources from the Chinese, Indian and developing economies have seen a resource boom (since 2005) in resource-rich Australia and resulted in a two-speed economy. One economy is the mining sector and the other economy being "all of the other industries". Although the mining boom has increased the overall employment levels, this increase comes at the expense of higher inflation. According to the World Bank, inflation (GDP Deflator) in Australia was 3.8% in 2005 and it rose to 6.1% in 2011. Such surge in inflation as a result of energy price inflation is often overlooked by central banks as there is an increase in employment and the overall economy is growing. Inflation pressures emerge when productivity is not maintained or when domestic cost pressures are not watched. This mining boom is expected to peak in early 2013 and fade in late 2013 (Colebatch, 2013; Glynn, 2013). Such expectation has the potential to increase overall unemployment levels significantly (as employment outside of the mining sector has been shrinking).

The resource boom has strengthened the Australian dollar and affected its exports and production base. This could lead to a lower level of productivity. Slowed productivity growth will flow through to higher cost and faster inflation. To boost productivity, economic restructuring is required especially in sectors affected by the high dollar. However, as the mining sector starts to wane, the dollar should react accordingly and restore the competitiveness of the other industries like the farmers, manufacturers, services, tourism, and the Universities. Adjustments will have to be made to cost and standard of living as income will fall.

As growth has been largely driven by the mining sector, it is only appropriate that policies be sustainable. Natural resources are not infinite; they will be used up eventually. Sustainable measures would ensure that the mining town remains self sufficient when mining activities cease to continue. To generate employment for the town population, eco-tourism and auxiliary services like tours to dormant mines and an information centre detailing the history of the mining town may be feasible. In addition, options geared towards investments of other industries will facilitate the eco-tourism initiative discussed earlier, for example construction of basic infrastructure and utilities.

5. CONCLUSION

Some of the significant findings from Chapter Six are presented in this analysis. The respective economies and their macroeconomic variables discussed were Australia (Inflation and Employment), Canada (Inflation), and the United Kingdom (Employment). The effect of an economy's capacity on the macroeconomic variables tends to be overstated in the standard macroeconomic model compared to the EM model in the case of inflation in Canada and employment in the UK. The rate of change (increasing or decreasing) of the macroeconomic variables tends to be smaller in the EM model relative to the standard macroeconomic model – except for inflation in Australia, where the rate of change is greater in the EM model. Finally, there are two different policy ranges for consideration when both the standard and the EM models are applied – and this was illustrated in the Australia context. The next and final chapter will conclude this study by presenting the implications of the results and a discussion of directions for future research.

Chapter Eight – A Summary of the Research and Limitations of the Study

1. INTRODUCTION

In this concluding chapter, a summary of the research will be discussed first, followed by directions for future research and conclusions. The summary of the research reviews what has been discussed in each of the chapters along with significant findings from the analysis that was performed. Limitations of the study are discussed in the next section before the conclusion.

2. SUMMARY OF THE RESEARCH

The main thrust of this research is to demonstrate methods for deriving a set of stabilisation policies that addresses not only output, employment, and inflation but also sustainability. In this section, a brief discussion of each chapter and of significant findings from the analysis will be presented.

Chapter One provided a synopsis of the standard macroeconomic framework and policy practices that stem from the utilisation of such a framework. Chapter Two reviewed the literature on environmental accounting and environmental-macroeconomics (EM). This review highlighted the challenges posed by standard frameworks when environmental capital (KN) was not internalised. As such, recommendations for the development of advanced macroeconomic modelling must be considered for sustainable policies to be formulated. Chapter Three provided recommendations for the proposed EM framework following the illustration of an introductory EM framework which was empirically tested.

However, enhancements are required for this model before it can be operationalised. These enhancements were accomplished in Chapters Four and Five, beginning with the measurement of KN in Chapter Four.

Chapter Four focused on the measurement of KN by factoring KN into the factor utilisation model. The empirical evidence was made with reference to 11 selected Organisation for Economic Co-operation and Development (OECD) economies namely Australia, Canada, France, Germany, Japan, Korea, Mexico, New Zealand, Norway, the United Kingdom and the USA, from 1980 to 2009. Chapter Five offered a comparison of the economies' steady state between the standard macroeconomic model and the EM model. Empirical evidence of the steady states for the two models was presented. It was found that the capacity of an economy can be overstated in the absence of KN. Such oversight (with no allowance rendered for KN) could have an effect on the steady state of an economy with respect to its macroeconomic goals of inflation, employment, and GDP growth.

Chapter Six presented a methodology for analysing how macroeconomic goals are related by steady states. An explanatory relationship between the macroeconomic variables and the steady state ratios was formalised using panel and linear regressions. This formalised relationship is operationalised with year 2009 data for both the standard macroeconomic and EM models. Chapter Seven elaborated on the significant findings of selected economies and their macroeconomic variables with considerable differences in their policy ranges (highlighted in Chapter Six). The respective economies and their macroeconomic variables were Australia (Inflation and Employment), Canada (Inflation), and the United Kingdom (UK) (Employment).

One would expect a macroeconomic variable to display similar traits across the economies in terms of their relationships with the steady state ratios [(k^* / k), (k^{**} / k)]. However, this type of similarity was not observed. The observation from the 2009 snapshots showed that inflation in Australia was positively related to its steady state ratios whilst inflation in Canada displayed an inverse relationship. A similar observation was made of the relationship between employment and steady state ratios. Employment was positive in Australia whilst in the UK it was inversely related to steady state ratios.

To recapitulate Chapter Seven, the relationship between inflation and steady state ratios in the standard macroeconomic model was below that of the EM model. Furthermore, the rate of change of inflation with respect to the steady state ratios in the standard macroeconomic model in Canada was greater than that of the EM model. This result implies that, to achieve a given reduction in inflation, the steady state ratio must be increased by a greater amount in the EM model than in the standard macroeconomic model. However, the rate of change in inflation in the standard macroeconomic model in Australia was gentler relative to that of the EM model. Hence, in the case of Australia, to achieve a given reduction in inflation, the decrease in the steady state ratio has to be smaller in the EM model. Regardless of the nature of the relationships between inflation and the steady state ratios and the gradients for the different models; it was observed that the effort to curb inflation was understated in the standard macroeconomic model for both Australia and Canada, simply because any increase or decrease in the steady state ratios is greater for the EM model compared to the standard macroeconomic model.

Following the findings from Chapter Seven, the relationship between employment and the steady state ratios in the standard macroeconomic models was above that of the EM model for the UK and below that of the EM model for Australia. The rate of change of employment with respect to the steady state ratios in the standard macroeconomic model in the UK was greater than that of the EM model. This relationship implies that, to achieve a given increase in employment, the steady state ratio in the EM model has to be increased by a greater amount compared with the case for the standard macroeconomic model. The rate of change in employment in the standard macroeconomic model in Australia was also greater (albeit marginal!) relative to that of the EM model. Hence, in the case of Australia, to achieve a given increase in employment, the increase in the steady state ratio will also need to be greater in the EM model. Regardless of the nature of the relationships between employment and the steady state ratios and the gradients for the different models, it was observed that the effort to curb unemployment was overstated in the standard macroeconomic model for both the UK and Australia, simply because any increase or decrease of the steady state ratios is greater for the EM model compared to the standard macroeconomic model.

The type of relationship (positive or inverse) between the macroeconomic variables and the steady state ratios determines whether policy makers should increase or decrease the steady state ratios. Consider the case of inflation for Australia and Canada. Inflation in Australia was positively related and was inversely related in Canada with respect to the steady state ratios. Policy makers prefer to reduce inflation to keep inflation in a manageable range. Thus, the steady state ratio should be decreased for Australia and increased in Canada. Next, consider employment for the UK and Australia. Employment in the UK was inversely related to the steady state ratios and was positively related in Australia. Policy makers would prefer to increase employment to sustain economic growth. Therefore, the steady state ratio should be decreased in the UK and increased for Australia. The observation made above presents a trade-off between inflation and employment in the Australia case. Increasing the steady state ratios increases employment but this will also increase inflation (Australia's inflation was positively sloped). As a consequence, policy makers in Australia have to be content with higher inflation levels when employment is increased.

3. LIMITATIONS OF THE STUDY

The limitations of the study are as follows:

i. The proxy selected for the depreciation of environmental capital (D_{KN}) is carbon dioxide (CO_2). CO_2 was chosen because the selected databank allows for the conversion of all other greenhouse gases (GHG) into CO_2 terms. This conversion allows for completeness in terms of capturing all CO_2 emissions. In addition, there are substantial emissions data dating back to 1970.

   If D_{KN} was not proxied to CO_2 alone and was extended to capture other considerations of KN, the output of the analysis might have been different. For example, if D_{KN} was extended to include deforestation, soil erosion and water pollution, then the size of KN might be considerably larger.

   If these were proxies for D_{KN}, the challenge would be to obtain a universally agreed measurement method for pollution.

ii. A possible enhancement that could be made to the model is to move away from the Cobb-Douglas framework to an endogenous framework such as the Romer model which considers different types of factor utilisation with constant or variable elasticity of substitution.

iii. Standard macroeconomic analysis factor utilisation frameworks serve as the basis for developing the aggregate supply (AS) framework. A possible extension is to develop the AS and combine it with the aggregate demand (AD) to effect a general equilibrium analysis. Such analysis can be differentiated between the standard macroeconomic model and the EM model.

iv. The snapshot selected for the analysis was for the year 2009. The year 2009 was selected because it had the latest, as well as being complete, set of required data at time of study. However, 2009 was the immediate year after the 2008 Global Financial Crisis (GFC). There is a possibility that this analysis could have been skewed as a result of the GFC exogenous shock. It might be wise for the analysis to be compared with another year where for the year preceding that there were no major exogenous shocks. Hence, a recommendation would be to select "stable" years with less volatility. For example, snapshots could be performed for the years 2007 and 2010.

   In addition, snapshots generated for the years 2007 and 2010 could be compared to see whether the findings are consistent. This comparison could help to generalise a predictive model for future time periods.

4. CONCLUSION

Policy discussions and debates abound when an economy is operating at, beyond or close to its steady state equilibrium (SSE). There is a portfolio of policies that is available to policy makers, such as monetary policy and fiscal policy (two of the more accessible approaches). The debate usually centres on who should bear the responsibility for steering an economy forward, specifically the Reserve Bank for monetary policy versus the Central Government for fiscal policy. However, these debates will add no value IF the policy range has not been correctly identified by the appropriate macroeconomic model – from the outset. This study argues that the EM model should be the macroeconomic model that is used for economies when determining the steady state of an economy as well as how the steady state affects the macroeconomic variables.

Bibliography

Ackerman, F., Stanton, E.A., DeCanio, S.J., Goodstein, E., Howarth, R.B., Norgaard, R.B., Norman, C.S., Sheeran, K.A. (2009), "The Economics of 350: The Benefits and Costs of Climate Stabilization", Economics for Equity and the Environment Network

Auffhammer, M., and Carson, T.C. (2008), "Forecasting the Path of China's CO_2 Emissions using Province-Level Information", Journal of Environmental Economics and Management, 55 (3), pp. 229 - 247

Amin, S. (1992), "Can environmental problems be subject to economic calculations?", World Development, 20, 4, pp. 523-530

Ananthaswamy, A. (2010), "Climate change blame game", New Scientist, 28th August 2010, pp. 14

Anderson, D. R., Sweeney, D. J. and Williams, T. A. (1976), *An Introduction to Management Science Quantitative Approaches to Decision Making – 2nd Edition*, West Publishing Company, St Paul, USA

Arin, K.P., Spagnolo, N. (2011), "Short-term growth effects of fiscal policy revisited: A Markov-switching approach", Economic Letters, 110, pp. 278-281

Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C.S., Jansson, B.O., Levin, S., Mäler, K.G., Perrings, C., Pimentel, D. (1995), "Economic Growth, Carrying Capacity, and the Environment", Science, Vol. 268, 28 April 1995, pp. 520-521

Arrow, et al. (2004), "Are We Consuming Too Much?", Journal of Economic Perspectives, 18, 3, pp. 147-172

Benyhus, J. (2002), *Biomimicry: Innovation Inspired by Nature*, Harper Perennial, UK

Blanchard, O. (2009), *Macroeconomics – Fifth Edition*, Pearson Education, Australia

Boersema, J.J. (2009), "Environmental sciences, sustainability, and quality" in Boersema, J.J., Reijnders, L. (eds), Principles of Environmental Sciences, Dordrecht/Berlin: Springer, pp. 3-15

Boersema, J.J. (2011) "Does the population issue still have a valid place on the environmental agenda?" in Kroeze, C., Boersema, J.J., Tellegen, E., Cremers, A. (ed) "Technology and Sustainability", Techne Press, Amsterdam, The Netherlands, pp. 9-16

Bonefeld, W. and Burnham, P., "1990-1992: Britain and the politics of the European exchange rate mechanism", Capital and Class (Autumn 1996), pp. 5-38

Booth, D.E. (2004), Hooked on Growth: Economic Addictions and the Environment, Lanham, Rowman and Littlefield

Boulding, K. (1949), "Income or Welfare?", Review of Economic Studies, 17, pp. 77-86

Boulding, K. (1966), "The Economics of the Coming Spaceship Earth", in Jarrett (ed), *Environmental Quality in a Growing Economy*, Baltimore, MD: Johns Hopkins University Press, pp. 3-15

Bovenberg, A. L., Goulder, L. H. (1996), "Optimal Equilibrium Taxation in the Presence of Other Taxes: General-Equilibrium Analyses", The American Economic Review, 86, 4, Sept 1996, pp. 985-1000

Braun, E., Wield, D. (1994), "Regulation as a means for the social control of technology', Technology Analysis & Strategic Management, 6 (3)

Brash, D.T. (2000), "The fall of the New Zealand dollar: why has it happened, and what does it mean?", The Reserve Bank of New Zealand, 5th Oct 2000

Brekke, J. A. (1997), "Hicksian Income from Resource Extraction in an Open Economy", Land Economics, 73, 4, pp. 516-527

Cannon, T. (1994), "Vulnerability Analysis and the Explanation of 'Natural' Disasters", in "Disasters, Development and Environment", ed A. Varley, John Wiley & Sons, England

Canterbery, E. R. (2001), *A Brief History of Economics – Artful Approaches to The Dismal Science*, World Scientific Publishing, Singapore

Carsons, R. T. (2007), *The Stated Preference Approach to Environmental Valuation – Volume III: Benefit-Cost Analysis and Natural Resource Damage Assessment*, (ed), Ashgate Publishing Company, UK

Case, K.E., Quigley, J.M., Shiller, R. (2005)" Comparing Wealth Effects: The Stock Market Versus the Housing Market" Working Paper W01-004, University of California at Berkeley

Chari, V. V., Kehoe, P. J., McGrattan, E. R. (2009), "New Keynesian Models: Not yet Useful for Policy Analysis", American Economic Journal: Macroeconomics 2009 Vol. 1, No. 1, pp. 242-266

Ciambrone, D. F. (1997), *Environmental Life Cycle Analysis*, USA, CRC Publishers

Colebatch, T. (2013), "Some Fear the Mining Boom will turn to Bust", The Age, 30th March 2013

Collier, P. (2010), *The Plundered Planet*, Oxford University Press, UK

Cropper, M. L., Oates, W. E. (1992) “Environmental Economics: A Survey”, Journal of Economic Literature, 30(2): 675-740

Daly, H.E. (1977), *Steady-State Economics, The Economics of Biophysical Equilibrium and Moral Growth,* W.H. Freemann and Company, San Francisco.

Daly, H.E. (1991), “Towards an Environmental Macroeconomics”, Land Economics, 67(2), pp. 255-59

Daly, H.E. (1993), “Sustainable Growth: An Impossible Theorem” in Valuing the Earth: Economics, Ecology, Ethics (eds) Daly, H.E., Townsend, K.N., pp. 267-273

Daly, H.E. (1996), *Beyond Growth*, Beacon Press, Boston, United States of America

Daly, H.E. (1996), “Comment: Is the Entropy Law Relevant to the Economics of Natural Resources Scarcity? – Yes, of Course It Is!”, Journal of Environmental Economics and Management, 23, pp. 91-95

Daly, H.E. (1997), Georgescu-Roegen versus Solow/Stiglitz – Forum”, Ecological Economics, Vol.22, pp. 261 – 266

Daly, H.E. (2007), *Ecological Economics and Sustainable Development, Selected Essays of Herman Daly*, Edward Elgar Northampton, MA, USA

Dasgupta, P., Kristöm, B., Mäler, K-G. (1994) “Current Issues in Resource Accounting”, Report 105, Umeå, Department of Forest Economics, Swedish University of Agricultural Sciences, Uppsala, Sweden

Dietz & Rosa (1994), “Rethinking the environmental impacts of population, affluence and technology”, Human Ecological Review, 1, pp. 277-300

Dixon, J.A., Scura, L.F., Carpenter, R.A., Sherman, P.B. (1997) “Economic Analysis of Environmental Impacts”, Earthscan Publications Ltd, London

Dornbusch, R., Fischer, S., Kearney, C. (1995), *Macroeconomics – Australian Edition*, McGraw-Hill Book Company, Sydney, Australia

Dornbusch, R., Fischer, S., Startz, R. (2008), *Macroeconomics – Tenth Edition*, McGraw-Hill Book Company, New York, United States of America

Doughtery, C. (2011) Introduction to Econometrics – Fourth Edition, Oxford University Press, United Kingdom, Chapter 14

Dyer, A. (2010), “Climate Spectator: Can a carbon tax cut it?”, Business Spectator, 27th October 2010

Ehrlich, P.R. (1968), The Population Bomb, New York: Ballantine

Ekins, P., Speck, S. (2000), “Proposals of Environmental Fiscal Reforms and the Obstacles to their Implementation”, Journal of Environmental Policy & Planning, 2, pp. 93-114

El Serafy, S. (2002), “The ‘El Serafy’ Method for Estimating Income from Extraction and its importance for Economic Analysis”, A Synoptic Paper

England, R.W. (2000), “Analysis – Nature Caporal and the theory of economic growth”, Ecological Economics, 37, pp. 425-431

Eurostat (1995), *European System of Accounts*, ISBN: 92-827-7954-8

Fiala, N. (2008), “Measuring sustainability: Why the ecological footprint is bad for economics and bad environmental science”, Ecological Economics, 67, pp. 519-525

Frank, R. H. (2003), *Microeconomics and Behavior – Fifth Edition*, McGraw-Hill Higher Education, New York, United States of America

Frank, R. H., Bernanke, B. S. (2009), *Principles of Economics – Fourth Edition*, McGraw-Hill Irwin, New York, United States of America

Friedman, M. (1968), The Role of Monetary Policy, *American Economic Review*, 58(1), March, pp. 1-21

Gago, A., Labandeira, X. (2000), “Towards a Green Tax Reform Model”, Journal of Environmental Policy & Planning, 2, pp. 25-37

Garnaut, R. (2008), The Garnaut Climate Change Review, 2008. “Final Report”, September 2008, Cambridge University Press, Cambridge, UK

Georgescu-Roegen, N. (1970). 'The Economics of Production', The Richard T. Ely Lecture, American Economic Review, 60, pp. 1-9

Georgescu-Roegen, N. (1971), *The Entropy Law and the Economic Process*, Harvard University Press, Cambridge, MA

Gitins, R. (2010), The Happy Economist, Allen & Unwin, NSW, Australia

Glynn, J. (2013), “Australia’s Jobless Rate Rose in March”, The Wall Street Journal, 12-14 April 2013

Goulder, L. H. (1995), “Environmental Taxation and the Double Dividend: A reader’s guide”, International Tax and Public Finance, vol. 2, pp. 155-182

Graedel, T., Allenby, B. (2001), *Industrial Ecology (2nd ed),* New York, USA, Prentice-Hall Publishers

GTZ (2006), "Urine diverting dry toilets project – Kunming, China", Ecosan Projects, 11/10/2006

Hanley, N., Shogren, F.J., White, B. (1997) "Environmental Economics in Theory and Practice", MacMillan Press Ltd, London

Harford, T. (2006), The Undercover Economist, Abacus, UK

Harris, L., Brander, M. (2011), "Technical Paper, Carbon reporting in Directors' Reports", January 2011, econometrica, UK

Harris, M., Fraser, I. (2002), "Natural resource accounting in theory and practice: A critical assessment", The Australian Journal of Agricultural and Resource Economics, 46:2, pp. 139-192

Hartman, E. (2008), "A promising oil alternative: Algae Energy", The Washington Post, 6th January 2008

Hartwick, J.M. (1978), "Investing returns from depleting renewable stocks and intergenerational equity", Economics Letters, Vol. 1, No. 1, pp. 85-88

Hartwick, J.M. (1991), "Degradation of Environmental Capital and National Accounting Procedures", European Economic Review, Vol. 35, No. 2-3, pp. 642-649

Hartwick, J. M. (1997), "Paying Down the Environmental Debt", Land Economics, 73, 4, pp. 508-515

Harvey, F. (2010), "Climate change: Lingering clouds", Comment Analysis, Financial Times, 29th August 2010

Haverkamp, J. (2010), "UN climate negotiations sputter amid structural problems", Reuters and AlertNet, 18th October 2010

Hecht, J. E. (2005), *National Environment Accounting – Bridging the Gap between Ecology and Economy*, Resources for the Future, Washington DC, United States of America

Helm, D. (2005), "Economic Instruments and Environmental Policy", The Economic and Social Review, Vol. 36, No. 3, pp. 205 – 228

Hessing, M., Howlett, M., Summerville, T. (2005), Canadian Natural Resource and Environmental Policy: Political Economy and Public Policy, 2nd Edition, UBC Press, Vancouver

Hicks, J. (1946), Value and Capital – 2nd Edition, Oxford University Press

Holt, R.P.F. (2005), "Post-Keynesian economics and sustainable development", International Journal of Environment, Workplace and Employment, Vol. 1, No. 2, pp. 174-186

Hope, C.W. (2011), "The Social Cost of CO_2 from the PAGE09 Model", Economics, Discussion Paper 2011-39, September 2011

Howarth, R. B. (1997), "Sustainability as Opportunity", Land Economics, 73, 4, pp. 569-579

Humphreys, M., Sachs, J., Stiglitz, J. (eds) (2007), *Escaping the Resource Curse*, Columbia University Press

Ison, S., Peake. S., Wall, S. (2002), *Environmental Issues and Policies*, Prentice Hall, London, United Kingdom

Kahn, J., Rivas, A. (2009), "The Sustainable Economic Development of Traditional Peoples", in Holt, R.P.F., Pressman, S., and Splash, C.L. (Eds.), *Post Keynesian and Ecological Economics – Confronting Environmental Issues*, Edward Elgar, UK

Kant, P. (2010), "REDD Should Create Jobs, Not Merely Bring Compensation", IGREC Web Publication No 13/2010

Karstad, P.I. (2012), "The Price on Carbon should Increase", Statoil Innovate Blog. 24th April 2012

Knetsch, J.L. (1994), "Environmental valuation: Some problems of wrong questions and misleading answers", Environmental Values, 3, pp. 351-368

Kolstad, C.D. (2000), Environmental Economics, Oxford University Press, New York

Kolstad, A., Krautkraemer, V. (1993), "Natural resource use and the environment", in Kneese, A.V., Sweeny, J.L. (Eds.), *Handbook of Natural Resource and Energy Economics*, Elsevier, Amsterdam

Krever, R. (1998), "Taxation Responses to Financial Turmoil", Asia-Pacific Tax Bulletin 452, pp. 454

Leung, G. C. K. (2011), "China's energy security: Perception and reality", Energy Policy, doi: 10.1016/j.enpol.2010.12.005

Linder, S. (1970), *The Harried Leisure Class*, New York, Columbia University Press

Lismoen, H. (1999), "Uncertainty hits oil sector", European Industrial Relations Observatory On-Line, 28th September 1999, http://www.eurofound.europa.eu/eiro/1999/09/feature/no9909149f.htm

Mankiw, N. G. (2004), *Principles of Macroeconomics – Third Edition*, Thomson South-Western, United States of America

Mankiw, N. G., Wilson, P., Quah, E. (2008), *Principles of Economics: An Asian Edition*, Cengage Learning, Singapore

Manner, M., Gowdy, J. (2010), “The Evolution of Social and Moral Behavior: Evolutionary Insights of Public Policy”, Ecological Economics, Vol. 69, Issue 4, pp. 753-761

McDonough, W., Braungart, M. (2002), *Cradle to Cradle: Remaking the Way We Make Things*, New York, USA, North Point Press

Mendelsohn, R., Falk, I. (1993) "The Economics of Controlling Stock Pollution: An Efficient Strategy for Greenhouse Gases", Journal of Environmental Economics and Management, 25, pp. 76-88

Mendelsohn, R. (2002) “Environmental Economics and Human Health” Environmental Health Perspectives 110 A118-A119

Moriarty, P., Honnery, D. (2011), “Is there an optimum level for renewable energy?”, Energy Policy, doi: 10.1016/j.enpol.2011.02.044

N.Z. Muller, Mendelsohn, R. and Nordhaus, W. (2011), “Environmental Accounting for Pollution in the United States Economy”, American Economic Review 101, August 2011, pp. 1649-1675

Munasinghe, M. (2001) “Macroeconomics and the Environmental”, Edward Elgar Publications, London

Myles, G. D. (2000), “Taxation and Economic Growth”, Fiscal Studies, vol. 21, no. 1, pp. 141-168

Nordhaus, W and Tobin, J (1972), Economic Growth, National Bureau of Economic Research, Columbia University Press, New York

Nordhaus, W.D. (1992) “Lethal Model II: The Limits to Growth Revisited,” *Brooking Papers on Economic Activity*, 1992:2

Nordhaus, W. N. (2010), “Carbon Taxes to Move Toward Fiscal Sustainability”, The Economists’ Voice, September 2010, Berkeley Electronic Press

Nunes, P.A.L.D., can den Bergh, J.C.J.M. (2001), “Economic Valuation of biodiversity: sense or nonsense?”, Ecological Economics, 39, pp. 203-222

OECD (2010), *Multilingual Summaries (October 2010), Taxation, Innovation and the Environment, Green Growth Strategy*

OECD (2012), *OECD Environmental Outlook to 2050: The Consequences of Inaction (March 2012)*

Parkinson, G (2010), “Climate Spectator: Playing Carbon Games”, Business Spectator Commentary, Australia, 18 Oct 2010

Parry, I. W. H., Bento, A. M. (2000), “Tax Deductions, Environmental Policy, and the “Double Dividend” Hypothesis, Journal of Environmental Economics and Management, 39, pp. 67-96

Pindyck, R. S., Rubinfeld, D. L., Koh, W. T. H. (2006), *Microeconomics – An Asian Perspective*, Prentice Hall, Singapore

Project Catalyst (2010), From Climate Finance to Financing Green Growth, December 2010

Rathzel, N., Uzzell, D., (2009), “Changing relations in global environmental change”, Global Environmental Change, doi: 10.1016/j.gloenvcha.2009.05.001

Reddy, B. S., Assenza, G.B., (2009), “The great climate debate”, Energy Policy, doi:10.1016/j.enpol.2009.03.064

Repetto, R., Magrath, W., Wells, M., Beer, C., Rossini, F. (1989) *Wasting Assets: Natural Resources in the National Income Accounts*, Washington, DC: World Resource Institute

Repetto, R., Cruz, W. with Solozano, R., de Camino, R., Woodward, R., Tosi, J., Watson, V., Visques, A., Villalobos, C., Jimnes, J. (1991) Accounts Overdue: Natural Resources Depletion in Costa Rica. Washington, DC: World Resource Institute

Repetto, R., Baliga, S. (1997) "Pesticides and Immunosuppression: The Public Health Risks", Health Policy and Planning, vol.12 (2), June, pp. 97-106

Repetto, R., Dias, D., (2006), “The True Picture?”, Environmental Finance, July-August 2006, pp. 44-45

Romer, P.M. (1986), “Increasing Returns and Long-Run Growth”, Journal of Political Economy, 94 (5), October, pp. 1002-37

Rothman, D.S. (1998), “Environmental Kuznets curves-real progress or passing the buck? A case for consumption-based approaches”, Ecological Economics 25, pp. 177-194

Rothwell, R., Zegveld, W. (1981), *Industrial Innovation and Public Policy: Preparing for the 1980s and the 1990s*, Frances Pinter, London

Rothwell, R. (1992), "Industrial innovation and government environmental regulation: some lessons from the past", Technovation, 12 (7), pp. 447-458

Samuelson, P. A., Nordhaus, W. D. (2001), *Economics – Seventeenth Edition*, McGraw-Hill Book Company, New York, United States of America

Sandmo, A. (2003), "Environmental Taxation and Revenue for Development", Discussion Paper No. 2003/86, United Nations University – World Institute for Development Economics Research

Schumacher, I. (2009), "The dynamics of environmentalism and the environment", Ecological Economics, doi: 10.1016/j.ecolecon.2009.06.004

Sedjo, R. A. (2010), "Comment on Nordhaus: Tax Carbon, Not Fossil Fuels", The Economists' Voice, October 2010, Berkeley Electronic Press

Sève, J. (2002), "A Discussion Paper on Environmental and Natural Resources Accounting and Potential Applications in African Countries", ENCAP IV, Subtask 5c, Environmental Policy and Institutional Strengthening Indefinite Quantity Contract (EPIQ), March 2002

Sinden, J.A. (1994), "A review of Environmental Valuation in Australia", Review of Marketing and Agricultural Economics, 62, 3, pp. 337-368

Smith, R., Lourie, B. (2009), *Slow Death by Rubber Duck*, Alfred A. Knopf, Canada

Solow, R. M. (1956) "A Contribution to the Theory of Economic Growth", Quarterly Journal of Economics, 70 (1) pp. 65-94

Solow, R. M. (1974), "The Economics of Resources or the Resources of Economics", American Economic Review, 64 (2), May, pp. 1-14

Solow, R.M. (1974), "Intergenerational Equity and Exhaustible Resources", The Review of Economic Studies, Vol. 41, pp. 29-45

Solow, R.M. (1986), "On the Intergenerational Allocation of Natural Resources", The Scandinavian Journal of Economics, Vol. 88, No. 1, pp. 141-149

Solow, Robert M. "Sustainability: An Economist's Perspective." Chapter 26 in *Economics of the Environment.* 5th ed. Edited by Robert N. Stavins. New York, NY: W.W. Norton & Company, 2005

Stafford, P. (2011), "Confusion over spot carbon trading restart", Financial Times, 26th January 2011

Statistics Netherlands (2009) Progress towards sustainability development in Netherlands, Sustainability Monitor for the Netherlands

Statistics New Zealand (2002) "Natural Resource Accounts for New Zealand – Overview Document", Christchurch

Stavins, R.N. (2007), "Environmental Economics", NBER Working Paper Series, Paper No. 13574

Stegman, T., Junor, B. (1993), *Introductory Macroeconomics*, Harcourt Brace Jovanovich, Sydney, Australia

Stern (2007) The Economics of Climate Change: The Stern Review, Cambridge University Press, UK

Sterner, T. (1994), "Environmental Tax Reform: The Swedish Experience", European Environment, 4, pp. 20-25

Stiglitz, J.E., Sen, A., Fitoussi, J-P (2009) Report by the Commission on the Measurement of Economic Performance and Social Progress, Paris

Swan, T. W. (1956) "Economic Growth and Capital Accumulation", Economic Record November, pp. 334-361

Tan, S., and Thampapillai, D.J. (2011), "Assessment of Fiscal Intervention Measures in China: Perspectives from Environmental Macroeconomics", *Critical Issues in Environmental Taxation, Volume IX*, Environmental Taxation in China and Asia-Pacific – Achieving Environmental Sustainability through Fiscal Policy, Edward Elgar, pp. 55 – 65, November 2011

Taylor, J. B., Williams, J. C. (2009), "A Black Swan in the Money Market", American Economic Journal: Macroeconomics 2009 Vol. 1, No. 1, pp. 58-83

Thampapillai, D.J., Maleka, P.T., Milimo, J.T. (1992), "Quantification of the trade-offs in Zambia between environment, employment, income and food-security", World Employment Programme Research, Working Paper [Case Study]

Thampapillai, D.J. (1993), "Environmental macroeconomics: Some conceptual considerations", Uppsala, Sweden

Thampapillai, D.J., Uhlin, H-E (1994), "On the measurement of environmental depreciation in macroeconomic analysis", Uppsala, Sweden

Thampapillai, D.J., Uhlin, H-E (1997), "Environmental capital and sustainable income: basic concepts and empirical tests", Cambridge Journal of Economics, 21, pp. 379-394

Thampapillai, D.J., Wanden, S., Larsson, M., Uhlin, H-E (1998), "The environment in macroeconomic analyses – comparisons between Sweden and the US", Australasian Journal of Regional Studies, 4, 2, pp. 349-362

Thampapillai, D.J., Hanf, C-H. (2000), "The internalization of environmental capital stocks into an aggregated cobb-douglas function", Economic Analysis & Policy, 30, 2, pp. 209-215

Thampapillai, D.J. (2002), *Environmental Economics – Concepts, Methods and Policies*, Oxford University Press, South Melbourne

Thampapillai, D.J., Thangavelu, S.M., Quah, E., & Padaya, P.M. (2005) "The Internalization of Environmental Capital in a Keynesian Model of Income Determination: Revised Approaches to Public Policy", Critical Issues in Environmental Taxation – International and Comparative Perspectives: Volume II, pp 85-95, Richmond Law & Tax Ltd

Thampapillai, D.J. (2007), "The scarcity of KN and economic growth: a comparative study of Australia and the US", The Singapore Economic Review, 52, 2 , pp. 251-263

Thampapillai, D.J. (2008), "The Environment as Capital", ETHOS World Cities Summit Issue June 2008, pp. 80-87

Thampapillai, D.J. (2008), "Environmental capacity constraints in macroeconomic policy analysis", International Journal of Environment, Workplace and Employment, 4, 1, pp. 1-14

Thampapillai, D.J., Wu, X. Tan, S. (2010), "Fiscal Balance: Environmental Taxes and Investments" Journal of Natural Resources Policy Research, Vol. 2, No. 2, pp. 137-147, April 2010

Thampapillai, D.J. (2012), "Macroeconomics versus Environmental-Macroeconomics", The Australian Journal of Agricultural and Resource Economics, 55, pp. 1-16

Thampapillai, D.J., and Sinden, J. (2012), Environmental Macroeconomics, *in press*

The Climate Institute (2010), "Putting a Price Tag on Pollution – Driving Competitiveness in the Clean Energy Economy", October 2010

Todaro, M. P., Smith, S. C. (2002), *Economic Development – 8th Edition*, Addison Wesley, UK

Tour, A. de la, Glachant, M., Ménière, Y. (2011), "Innovation and international technology transfer: The case of the Chinese photovoltaic industry", Energy Policy, 39, pp. 761-770

Tsang, S., Kolk, A. (2010), "The Evolution of Chinese Policies and Governance Structures on Environment, Energy and Climate", Environmental Policy & Governance, 20, 3, May/June 2010

United Nations et al. (1993), System of National Accounts

United Nations et al. (2008), System of National Accounts

UNU-IHDP and UNEP (2012), *Inclusive Wealth Report 2012 – Measuring progress toward sustainability*, Cambridge: Cambridge University Press

United States Department of Agriculture, Economic Research Service, The Economics of Food, Farming, Natural Resources, and Rural America. Data Sets, Fertilizer Prices (Updated 18 May, 2010)

Vincent, J.R. (1999) "A framework for forest accounting", Forest Science 45(4):1-10

Vincent, J.R. (2000) "Green accounting: from theory to practice", Environment and Development Economics 5(1&2):13-24

Welsch, H. (2009), "Implications of happiness research for environmental economics", Ecological Economics, doi: 10.1016/j.ecolecon.2009.06.003

Win, T. L. (2011), "World ponders alternatives to troubled carbon market", AlertNet, 24th January 2011

Wolf, M. (2012), "The world's hunger for public goods", Financial Times, 25th January 2012

World Bank (2007), World Development Indicators (Washington DC: World Bank)

World Bank (2010), World Development Indicators, On-Line Edition, 2010

Xu, Y., Halkyard, A. (2010), "The impact of the Global Financial Crisis on Broadly Based Indirect Taxation: A Chinese Case Study", eJournal of Tax Research, 8, 2, pp. 188-214, December 2010, Atax, The University of New South Wales

Zhou, Y., Rengifo, C., Chen, P., Hinze, J. (2011), "Is China ready for its nuclear expansion?", Energy Policy, 39, pp. 771-781

<u>Appendices</u>

Appendix 2.1

<u>List of issues pertaining to the revision of the SEEA-2003</u>

Issues for Volume 1	Issue papers	Outcome papers	Global consultation deadline	Number of comments
1. Harmonization of MFA with the SEEA concepts		✔	1/17/2011	
1.a. Recording of cultivated biological resources	✔			
1.b. Treatment of consumer durables	✔			
1.c. Recording of landfills	✔			
2. Definitions and classifications of physical flows	✔	✔	1/17/2011	
3. Linking energy flow accounts, energy balances and energy basic statistics and emission inventories and accounts				
3.a. Linking energy flow accounts, energy balances and energy statistics	✔	✔	12/24/2010	6
3.b. Linking emission inventories to emission accounts	✔	✔	12/24/2010	6
4. Renewable energy	✔	✔	10/28/2010	22
5. Environment industry	✔	✔	11/25/2010	30
6. Environmental taxes	✔	✔	11/25/2010	30
7. Environmental subsidies	✔	✔	11/25/2010	27
8. Permits				
8.a. Permits to access the resources				
8.b. Emission permits	✔			
9. Classification of natural resource management expenditures	✔	✔	11/25/2010	26

10.	Classification of assets	✓	✓	1/17/2011	
11.	Categorization of mineral and energy resources	✓	✓	12/24/2010	6
12.	Valuation of assets	✓	✓	12/6/2010	27
13.	Recording of natural resource depletion for a non-renewable resource	✓	✓	10/28/2010	19
14.	Recording of natural resource depletion for renewable resources	✓	✓	10/28/2010	20
15.	Decommissioning costs and recording ownership of mineral-related assets				
15.a.	Decommissioning costs	✓	✓	10/28/2010	18
15.b.	Recording ownership of mineral-related assets	✓	✓	10/28/2010	14
16.	Treatment of water in artificial reservoirs	✓	✓	1/17/2011	
17.	Recording of losses (storage, distribution, transformation, theft)	✓	✓	12/24/2010	6
18.	Valuation of water				
19.	Land				
19.a.	Land use classification	✓	✓	1/17/2011	
19.b.	Land cover classification	✓	✓	1/17/2011	
20.	Recording of soil and its valuation	✓	✓	12/6/2010	26
21.	Forest accounts		✓	12/6/2010	23
21.a.	Classification of forests	✓			
21.b.	Carbon sequestration	✓			

Appendix 3.1

Table 3.1.1: Basic Macro Aggregates

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
C	1.9E+12	2E+12	2.2E+12	2.4E+12	2.7E+12	3.1E+12	3.4E+12	3.7E+12	4E+12	4.3E+12	4.6E+12	4.8E+12	5.1E+12	5.4E+12	5.7E+12	6.1E+12	6.6E+12
I	1.3E+12	1.5E+12	1.7E+12	2.3E+12	2.5E+12	2.7E+12	2.9E+12	3E+12	3.2E+12	3.4E+12	3.5E+12	3.9E+12	4.4E+12	5.3E+12	6.1E+12	6.9E+12	7.8E+12
G	5.2E+11	6.2E+11	7.2E+11	8.1E+11	9.1E+11	9E+11	1E+12	1.1E+12	1.2E+12	1.4E+12	1.6E+12	1.7E+12	1.9E+12	2E+12	2.1E+12	2.3E+12	2.5E+12
X – M	1.3E+11	1.4E+11	8.1E+10	-1.1E+11	1.1E+11	1.5E+11	1.5E+11	3.5E+11	3.7E+11	2.6E+11	2.4E+11	2.3E+11	3E+11	2.8E+11	3.6E+11	8.7E+11	1.4E+12
GDP	3.8E+12	4.2E+12	4.7E+12	5.5E+12	6.2E+12	6.9E+12	7.5E+12	8.2E+12	8.7E+12	9.3E+12	9.9E+12	1.1E+13	1.2E+13	1.3E+13	1.4E+13	1.6E+13	1.8E+13
T	2E+11	2.4E+11	2.9E+11	4.1E+11	4.2E+11	4.4E+11	4.7E+11	5.8E+11	6.7E+11	7.9E+11	8.6E+11	1E+12	1.2E+12	1.4E+12	1.5E+12	1.7E+12	2E+12
$\bar{I}$	9.5E+11	1.1E+12	1.5E+12	2E+12	2.1E+12	2.3E+12	2.4E+12	2.6E+12	2.9E+12	3.1E+12	3.4E+12	3.7E+12	4.3E+12	5.1E+12	5.8E+12	6.6E+12	7.4E+12
GDP Deflator	50.720	54.194	58.658	67.528	81.443	92.631	98.592	100.083	99.224	97.979	100.000	102.052	102.649	105.329	112.611	117.036	121.466
GDP Deflator Base = 1	0.507	0.542	0.587	0.675	0.814	0.926	0.986	1.001	0.992	0.980	1.000	1.021	1.026	1.053	1.126	1.170	1.215
Cost of air pollution @USD40/ton	1.2E+12	1.3E+12	1.3E+12	1.4E+12	1.5E+12	1.6E+12	1.6E+12	1.6E+12	1.6E+12	1.6E+12	1.7E+12	1.7E+12	1.8E+12	2E+12	2.2E+12	2.4E+12	2.6E+12
Cost of soil degradation @USD400/ton	5.3E+10	5.8E+10	5.7E+10	4.9E+10	5.6E+10	6.9E+10	7E+10	6.9E+10	7E+10	7.1E+10	6.7E+10	6.9E+10	8.6E+10	7.8E+10	9.2E+10	9.2E+10	1.1E+11
Y*	3.8E+12	4.2E+12	4.7E+12	5.5E+12	6.2E+12	6.9E+12	7.5E+12	8.2E+12	8.7E+12	9.3E+12	9.9E+12	1.1E+13	1.2E+13	1.3E+13	1.4E+13	1.6E+13	1.8E+13
Y**	1.7E+12	2E+12	2.5E+12	3.1E+12	3.7E+12	4.1E+12	4.7E+12	5.3E+12	6E+12	6.5E+12	7E+12	7.8E+12	8.7E+12	9.7E+12	1.1E+13	1.2E+13	1.4E+13
Y_A	3.7E+12	4E+12	4.6E+12	5.2E+12	5.9E+12	6.6E+12	7.2E+12	7.9E+12	8.5E+12	9.2E+12	9.9E+12	1.1E+13	1.2E+13	1.3E+13	1.4E+13	1.6E+13	1.8E+13

Table 3.1.2: Coefficients

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Φ	1.6E+12	1.9E+12	2.2E+12	2.7E+12	3.1E+12	3.3E+12	3.6E+12	4.1E+12	4.5E+12	4.8E+12	5.2E+12	5.7E+12	6.4E+12	7.3E+12	8.2E+12	9.8E+12	1.1E+13
β	0.512	0.500	0.499	0.481	0.465	0.477	0.488	0.487	0.491	0.503	0.509	0.499	0.485	0.466	0.446	0.422	0.407
δ	0.098	0.079	0.057	0.065	0.060	0.072	0.064	0.049	0.032	0.027	0.010	0.018	0.016	0.018	0.025	0.018	0.019
τ	0.052	0.057	0.062	0.074	0.068	0.064	0.062	0.071	0.077	0.085	0.088	0.095	0.100	0.106	0.107	0.107	0.107
γ^{AP}	0.325	0.310	0.285	0.259	0.240	0.230	0.217	0.199	0.180	0.175	0.168	0.159	0.151	0.154	0.157	0.150	0.142
γ^{SD}	0.014	0.014	0.012	0.009	0.009	0.010	0.009	0.009	0.008	0.008	0.007	0.006	0.007	0.006	0.006	0.006	0.006
γ_t	0.339	0.324	0.297	0.268	0.249	0.240	0.227	0.208	0.188	0.183	0.175	0.165	0.158	0.160	0.164	0.156	0.148

Trend Equations

Trend equations are estimated based on the coefficients in Table 4.1.2 to forecast the change in the respective parameters across the projected time period. The equations are listed below for each of the coefficients.

$\Phi(t)$: $y = 1.1082x$

$\beta(t)$: $y = 0.9755x$

$\delta(t)$: $y = 1.0482x$

$\tau(t)$: $y = 1.0472x$

$\gamma(t)$: $y = 0.9711x$

Table 3.1.3: Projection analysis in relation to Figure 1 with no taxes and no reinvestment

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Φ	8.2E+12	9.1E+12	1E+13	1.1E+13	1.2E+13	1.4E+13	1.5E+13	1.7E+13	1.9E+13	2.1E+13	2.3E+13	2.5E+13	2.8E+13	3.1E+13	3.5E+13	3.8E+13
β	0.446	0.435	0.425	0.414	0.404	0.394	0.385	0.375	0.366	0.357	0.348	0.340	0.331	0.323	0.315	0.308
δ	0.025	0.026	0.028	0.029	0.031	0.032	0.034	0.035	0.037	0.039	0.040	0.042	0.044	0.047	0.049	0.051
τ	0.107	0.113	0.118	0.123	0.129	0.135	0.142	0.148	0.155	0.163	0.170	0.178	0.187	0.196	0.205	0.215
γ_t	0.164	0.163	0.161	0.160	0.159	0.158	0.156	0.155	0.154	0.153	0.152	0.151	0.149	0.148	0.147	0.146
$\Delta\tau$	0.439	0.446	0.453	0.460	0.468	0.475	0.483	0.490	0.498	0.506	0.514	0.522	0.531	0.539	0.548	0.556
Y^*	1.4E+13	1.5E+13	1.7E+13	1.8E+13	2E+13	2.2E+13	2.4E+13	2.6E+13	2.9E+13	3.1E+13	3.4E+13	3.7E+13	4.1E+13	4.5E+13	4.9E+13	5.4E+13
Y^{**}	1.1E+13	1.2E+13	1.3E+13	1.4E+13	1.5E+13	1.7E+13	1.8E+13	2E+13	2.2E+13	2.5E+13	2.7E+13	3E+13	3.3E+13	3.6E+13	4E+13	4.4E+13
Y_A	1.4E+13	1.6E+13	1.8E+13	2E+13	2.2E+13	2.4E+13										

Table 3.1.4A: Projection analysis in relation to Figure 4 with tax at 2 per cent but no reinvestment

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
$\Phi*$	8.20494E+12	9.09271E+12	1.00765E+13	1.11668E+13	1.23751E+13	1.37141E+13	1.51979E+13	1.68423E+13	1.86647E+13	2.06842E+13	2.29222E+13	2.54024E+13
$\Phi**$	8.20494E+12	9.09271E+12	1.00765E+13	1.11668E+13	1.23751E+13	1.37141E+13	1.51979E+13	1.68423E+13	1.86647E+13	2.06842E+13	2.29222E+13	2.54024E+13
β	0.446	0.435	0.425	0.414	0.404	0.394	0.385	0.375	0.366	0.357	0.348	0.340
δ	0.025	0.026	0.028	0.029	0.031	0.032	0.034	0.035	0.037	0.039	0.040	0.042
τ	0.107	0.113	0.118	0.123	0.129	0.135	0.142	0.148	0.155	0.163	0.170	0.178
γ_t	0.164	0.154	0.146	0.137	0.129	0.122	0.115	0.112	0.108	0.105	0.102	0.099
γ_t^{AP}	0.157	0.148	0.140	0.132	0.124	0.117	0.111					
γ_t^{SD}	0.006	0.006	0.006	0.005	0.005	0.005	0.004					
γ_t								0.110	0.104	0.099	0.096	0.093
$\Delta\tau$	0.02	0.02	0.02									
Reforest	-	5,904,972	13,579,681	22,106,696								
Organic	-	5,904,972	13,579,681	22,106,696								
		11,809,944	27,159,363	44,213,392								
Y*	1.40162E+13	1.52583E+13	1.66239E+13	1.83726E+13	2.00359E+13	2.18656E+13	2.38787E+13	2.60943E+13	2.85333E+13	3.12191E+13	3.41773E+13	3.74367E+13
Y**	1.05014E+13	1.16784E+13	1.29753E+13	1.45602E+13	1.61484E+13	1.78988E+13	1.98281E+13	2.19095E+13	2.42201E+13	2.6771E+13	2.94924E+13	3.24979E+13
Y_A	1.41975E+13	1.58018E+13	1.78086E+13	2.03374E+13	2.22898E+13	2.43182E+13						

<u>Table 3.1.4B: Projection analysis in relation to Figure 4 with tax at 5 per cent but no reinvestment</u>

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Φ^*	8.20494E+12	9.09271E+12	1.00765E+13	1.11668E+13	1.23751E+13	1.37141E+13	1.51979E+13	1.68423E+13	1.86647E+13	2.06842E+13	2.29222E+13	2.54024E+13
Φ^{**}	8.20494E+12	9.09271E+12	1.00765E+13	1.11668E+13	1.23751E+13	1.37141E+13	1.51979E+13	1.68423E+13	1.86647E+13	2.06842E+13	2.29222E+13	2.54024E+13
β	0.446	0.435	0.425	0.414	0.404	0.394	0.385	0.375	0.366	0.357	0.348	0.340
δ	0.025	0.026	0.028	0.029	0.031	0.032	0.034	0.035	0.037	0.039	0.040	0.042
τ	0.107	0.113	0.118	0.123	0.129	0.135	0.142	0.148	0.155	0.163	0.170	0.178
γ_t	0.164	0.154	0.146	0.137	0.129	0.122	0.115	0.112	0.108	0.105	0.102	0.099
γ_t^{AP}	0.157	0.148	0.140	0.132	0.124	0.117	0.111					
γ_t^{SD}	0.006	0.006	0.006	0.005	0.005	0.005	0.004					
γ_t								0.107	0.098	0.090	0.088	0.085
$\Delta\tau$	0.05	0.05	0.05									
Reforest	-	14,513,769	33,384,058	54,357,570								
Organic	-	14,513,769	33,384,058	54,357,570								
		29,027,537	66,768,116	108,715,140								
Y*	1.37028E+13	1.49311E+13	1.62817E+13	1.83726E+13	2.00359E+13	2.18656E+13	2.38787E+13	2.60943E+13	2.85333E+13	3.12191E+13	3.41773E+13	3.74367E+13
Y**	1.03245E+13	1.14858E+13	1.27659E+13	1.45602E+13	1.61484E+13	1.78988E+13	1.98281E+13	2.20125E+13	2.44565E+13	2.71549E+13	2.98978E+13	3.29264E+13
Y_A	1.41975E+13	1.58018E+13	1.78086E+13	2.03374E+13	2.22898E+13	2.43182E+13						

Appendix 5.1

C-D Production Function and Steady State Values

The C-D function is one that displays constant returns to scale. In other words

$$Y = \alpha KM^{\theta} L^{1-\theta} \qquad (5A.1)$$

Income, Y is divided by L to express the equation in terms of the output per worker (Y / L) as a function of the capital per worker (KM / L)

$$y = \frac{Y}{L} = \alpha \frac{KM^{\theta} L^{1-\theta}}{L} = \alpha (\frac{KM}{L})^{\theta} \qquad (5A.2)$$

$$y = \alpha k^{\theta} \quad \text{where} \quad k = \frac{KM}{L} \qquad (5A.3)$$

The savings per worker is explained by multiplying (5A.3) by the savings ratio (ρ)

$$\rho y = \rho \alpha k^{\theta} \qquad (5A.4)$$

Lets assume that there is a need for new workers and that depreciated capital must be replaced. The rate of entry of new workers is η, and the rate of depreciation is δ. The savings per worker is then defined as

$$\rho y = (\delta + \eta) k \qquad (5A.5)$$

To solve for k^*, equate (5.A4) and (5.A5), as follows:

$$(\delta + \eta) k = \rho \alpha k^{\theta} \qquad (5A.6)$$

Rearranging (5A.6),

$$k^{1-\theta} = \frac{\rho \alpha}{(\delta + \eta)} \qquad (5A.7)$$

The steady state value of k is

$$k^* = \left[\frac{\rho\alpha}{\delta+\eta}\right]^{\frac{1}{1-\theta}} \tag{5A.8}$$

Appendix 5.2

<u>Revised C-D Production Function and Steady State Values</u>

The revised C-D function is one that displays constant returns to scale. In other words

$$Y = \alpha k^{\theta'} L^{\lambda'} KN^{\phi} \tag{5A.9}$$

Income, Y is divided by L to express the equation in terms of the output per worker (Y / L) as a function of the capital per worker (KM / L)

$$y = \frac{Y}{L} = \alpha \frac{k^{\theta'} L^{\lambda'} KN^{\phi}}{L} = \alpha k^{\theta'} L^{\lambda'-1} KN^{\phi} \tag{5A.10}$$

For the index of L, $\theta' + \lambda' + \phi = 1, \lambda' = 1 - \theta' - \phi, \lambda' - 1 = -\theta' - \phi, \lambda' - 1 = -(\theta' + \phi)$

Equation (5A.10) can be expressed as

$$y = \alpha k^{\theta'} L^{-(\theta'+\phi)} KN^{\phi} \tag{5A.11}$$

Rearranging (5A.11),

$$y = \frac{\alpha k^{\theta'} KN^{\phi}}{L^{\theta'+\phi}} = \frac{\alpha k^{\theta'} KN^{\phi}}{L^{\theta'} L^{\phi}} = \alpha \left(\frac{K}{L}\right)^{\theta'} \left(\frac{KN}{L}\right)^{\phi} \tag{5A.12}$$

$$y = \alpha k^{\theta'} kn^{\phi} \quad \text{where} \quad k = \frac{K}{L}, \quad kn = \frac{KN}{L} \tag{5A.13}$$

The savings per worker is explained by multiplying (5A.13) by the savings ratio (ρ)

$$\rho y = \rho \alpha k^{\theta'} kn^{\phi} \tag{5A.14}$$

As shown in Appendix 5.1, the steady state equilibrium k^{**} can be defined by equating (5A.14) with the rate of entry of new workers η, the rate of capital depreciation δ, and the rate of environmental capital depreciation δ_{kn}

$$\rho\alpha k^{\theta'} kn^{\phi} = (\delta + \eta)k + \delta_{kn} \tag{5A.15}$$

Because KN is costed and depreciated in the same way as KM, it can be expressed as a function of KM. In other words

$$kn = \gamma k \tag{5A.16}$$

Substituting (5A.16) into (5A.15)

$$\rho\alpha k^{\theta'} (\gamma k)^{\phi} = Dk + \delta(\gamma k) \tag{5A.17}$$

where D = δ + η

Rearranging (5A.17),

$$\frac{k}{k^{\theta'+\phi}} = k^{1-\theta'-\phi} = \frac{\rho\alpha\gamma^{\phi}}{D + \delta\gamma} \tag{5A.18}$$

The steady state value of k is

$$k^{**} = \left[\frac{\rho\alpha\gamma^{\phi}}{D + \gamma\delta_{KN}}\right]^{\frac{1}{1-\theta'-\phi}} \tag{5A.19}$$

Appendix 6.1

Regression Output

- *JAP (regression)*

Inflation (k^* / k)

```
. reg  lndeflatorratio lny lngdpgrowthratio,r

Linear regression                                      Number of obs =      29
                                                       F(  2,    26) =   20.29
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.6536
                                                       Root MSE      =  .00874

------------------------------------------------------------------------------
             |               Robust
lndeflator~o |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         lny |   .0180554   .0091818     1.97   0.060    -.0008181    .0369289
lngdpgrowt~o |   .6244478   .1727018     3.62   0.001     .2694543    .9794413
       _cons |  -.0149234   .0023563    -6.33   0.000    -.0197669   -.0100799
------------------------------------------------------------------------------
```

Inflation (k^{**} / k)

```
. reg  lndeflatorratio lny1 lngdpgrowthratio,r

Linear regression                                      Number of obs =      29
                                                       F(  2,    26) =   19.48
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.6472
                                                       Root MSE      =  .00882

------------------------------------------------------------------------------
             |               Robust
lndeflator~o |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        lny1 |   .0164014   .0091344     1.80   0.084    -.0023746    .0351775
lngdpgrowt~o |   .6313003   .1752478     3.60   0.001     .2710732    .9915274
       _cons |  -.0127808   .0022753    -5.62   0.000    -.0174577   -.0081039
------------------------------------------------------------------------------
```

Employment (k^* / k)

```
. reg  lnemploymentratio lny lngdpgrowthratio,r

Linear regression                                      Number of obs =      29
                                                       F(  2,    26) =   21.69
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.6334
                                                       Root MSE      =  .00587

------------------------------------------------------------------------------
             |               Robust
lnemployme~o |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         lny |   .0152381   .0054589     2.79   0.010     .0040173     .026459
lngdpgrowt~o |   .3493416   .0819443     4.26   0.000     .1809026    .5177806
       _cons |  -.0063966   .0022514    -2.84   0.009    -.0110245   -.0017688
------------------------------------------------------------------------------
```

Employment (k^{**} / k)

```
. reg  lnemploymentratio lny1 lngdpgrowthratio,r

Linear regression                                      Number of obs =      29
                                                       F(  2,    26) =   21.49
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.6319
                                                       Root MSE      =  .00588

------------------------------------------------------------------------------
             |               Robust
lnemployme~o |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        lny1 |   .0145112   .0051719     2.81   0.009     .0038803    .0251422
lngdpgrowt~o |   .3488052   .0821523     4.25   0.000     .1799387    .5176716
       _cons |  -.0045799   .0020349    -2.25   0.033    -.0087628   -.0003971
------------------------------------------------------------------------------
```

GDP growth (k^{*} / k)

```
. reg  lngdpgrowthratio lny lndeflatorratio lnemploymentratio,r

Linear regression                                      Number of obs =      29
                                                       F(  3,    25) =   24.41
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.6589
                                                       Root MSE      =  .00865

------------------------------------------------------------------------------
             |               Robust
lngdpgrowt~o |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         lny |  -.0026545   .0077132    -0.34   0.734    -.0185403    .0132312
lndeflator~o |   .5111284   .1474932     3.47   0.002     .2073605    .8148963
lnemployme~o |   .5780125   .2250069     2.57   0.017     .1146022    1.041423
       _cons |   .0160778   .0019018     8.45   0.000      .012161    .0199947
------------------------------------------------------------------------------
```

GDP growth (k^{**} / k)

```
. reg  lngdpgrowthratio lny1 lndeflatorratio lnemploymentratio,r

Linear regression                                      Number of obs =      29
                                                       F(  3,    25) =   24.09
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.6583
                                                       Root MSE      =  .00866

------------------------------------------------------------------------------
             |               Robust
lngdpgrowt~o |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        lny1 |  -.0015791   .0075515    -0.21   0.836    -.0171317    .0139735
lndeflator~o |   .5056154   .1466869     3.45   0.002      .203508    .8077228
lnemployme~o |   .5674102   .2253352     2.52   0.019     .1033236    1.031497
       _cons |   .0156628   .0014171    11.05   0.000     .0127441    .0185814
------------------------------------------------------------------------------
```

- *KOR (regression)*

Inflation (k^* / k)

```
. reg  lndeflatorratio lny  lngdpgrowthratio,r

Linear regression                                      Number of obs =      30
                                                       F(  2,    27) =    9.79
                                                       Prob > F      =  0.0006
                                                       R-squared     =  0.3418
                                                       Root MSE      =  .03815
```

lndeflator~o	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lny	.1570495	.0601073	2.61	0.014	.0337194	.2803795
lngdpgrowt~o	-2.324078	1.203075	-1.93	0.064	-4.792585	.1444281
_cons	.0453825	.0233836	1.94	0.063	-.0025966	.0933616

Inflation (k^{**} / k)

```
. reg  lndeflatorratio lny1 lngdpgrowthratio,r

Linear regression                                      Number of obs =      30
                                                       F(  2,    27) =    9.73
                                                       Prob > F      =  0.0007
                                                       R-squared     =  0.3358
                                                       Root MSE      =  .03832
```

lndeflator~o	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lny1	.1545458	.0593932	2.60	0.015	.0326811	.2764105
lngdpgrowt~o	-2.546	1.292616	-1.97	0.059	-5.198229	.1062282
_cons	.0769678	.0339067	2.27	0.031	.007397	.1465385

Employment (k^* / k)

```
. reg  lnemploymentratio lny lndeflatorratio ,r

Linear regression                                      Number of obs =      30
                                                       F(  2,    27) =    5.15
                                                       Prob > F      =  0.0127
                                                       R-squared     =  0.2197
                                                       Root MSE      =  .01873
```

lnemployme~o	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lny	.027136	.008513	3.19	0.004	.0096688	.0446032
lndeflator~o	-.0997527	.049231	-2.03	0.053	-.2007664	.0012611
_cons	-.0007885	.007765	-0.10	0.920	-.0167208	.0151439

Employment (k^{**} / k)

```
. reg  lnemploymentratio lny1 lndeflatorratio ,r

Linear regression                                      Number of obs =      30
                                                       F(  2,    27) =    5.12
                                                       Prob > F      =  0.0130
                                                       R-squared     =  0.2161
                                                       Root MSE      =  .01878

------------------------------------------------------------------------------
             |               Robust
lnemployme~o |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        lny1 |    .024792   .0078011     3.18   0.004     .0087855    .0407985
lndeflator~o |  -.0955411   .0484685    -1.97   0.059    -.1949904    .0039081
       _cons |   .0037651   .0066367     0.57   0.575    -.0098524    .0173825
------------------------------------------------------------------------------
```

GDP growth (k^{*} / k)

```
. reg  lngdpgrowthratio lny lndeflatorratio,r

Linear regression                                      Number of obs =      30
                                                       F(  2,    27) =  156.56
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.9012
                                                       Root MSE      =  .00615

------------------------------------------------------------------------------
             |               Robust
lngdpgrowt~o |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         lny |   .0474042    .003091    15.34   0.000     .0410621    .0537464
lndeflator~o |  -.0604056   .0191496    -3.15   0.004    -.0996974   -.0211138
       _cons |   .0177342   .0023975     7.40   0.000      .012815    .0226534
------------------------------------------------------------------------------
```

GDP growth (k^{**} / k)

```
. reg  lngdpgrowthratio lny1 lndeflatorratio ,r

Linear regression                                      Number of obs =      30
                                                       F(  2,    27) =  178.06
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.9150
                                                       Root MSE      =  .00571

------------------------------------------------------------------------------
             |               Robust
lngdpgrowt~o |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        lny1 |   .0440593   .0026493    16.63   0.000     .0386234    .0494952
lndeflator~o |  -.0564478   .0177441    -3.18   0.004    -.0928557   -.0200399
       _cons |   .0252786   .0019511    12.96   0.000     .0212753     .029282
------------------------------------------------------------------------------
```

- *UK (regression)*

Inflation (k^* / k)

```
. reg  lndeflatorratio lny lnemploymentratio lngdpgrowthratio,r

Linear regression                                      Number of obs =      30
                                                       F(  3,    26) =    5.63
                                                       Prob > F      =  0.0041
                                                       R-squared     =  0.6452
                                                       Root MSE      =  .02157
```

lndeflator~o	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lny	.1868053	.0487694	3.83	0.001	.0865584	.2870522
lnemployme~o	.4320378	.2750999	1.57	0.128	-.1334382	.9975138
lngdpgrowt~o	-3.037083	1.001845	-3.03	0.005	-5.096403	-.9777616
_cons	.0688838	.0179285	3.84	0.001	.0320312	.1057364

Inflation (k^{**} / k)

```
. reg  lndeflatorratio lny1 lngdpgrowthratio,r

Linear regression                                      Number of obs =      30
                                                       F(  2,    27) =    6.96
                                                       Prob > F      =  0.0037
                                                       R-squared     =  0.5737
                                                       Root MSE      =   .0232
```

lndeflator~o	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lny1	.1991056	.0571336	3.48	0.002	.0818772	.3163341
lngdpgrowt~o	-2.548432	.8877789	-2.87	0.008	-4.370004	-.72686
_cons	.0955858	.0219014	4.36	0.000	.0506479	.1405237

Employment (k^* / k)

```
. reg  lnemploymentratio lny lndeflatorratio lngdpgrowthratio,r

Linear regression                                      Number of obs =      30
                                                       F(  3,    26) =    6.34
                                                       Prob > F      =  0.0023
                                                       R-squared     =  0.3807
                                                       Root MSE      =  .01433
```

lnemployme~o	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lny	-.0633438	.0258623	-2.45	0.021	-.1165044	-.0101831
lndeflator~o	.1906347	.0906799	2.10	0.045	.0042394	.37703
lngdpgrowt~o	1.778733	.4331618	4.11	0.000	.8883558	2.669109
_cons	-.0296595	.0116542	-2.54	0.017	-.053615	-.005704

Employment (k^{**} / k)

```
. reg  lnemploymentratio lny1 lndeflatorratio lngdpgrowthratio,r

Linear regression                                      Number of obs =      30
                                                       F(  3,    26) =    5.36
                                                       Prob > F      =  0.0052
                                                       R-squared     =  0.3338
                                                       Root MSE      =  .01486
```

lnemployme~o	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lny1	-.0525896	.0340547	-1.54	0.135	-.1225902	.0174109
lndeflator~o	.1288231	.0941211	1.37	0.183	-.0646456	.3222919
lngdpgrowt~o	1.648519	.4404926	3.74	0.001	.7430736	2.553965
_cons	-.0364275	.0130325	-2.80	0.010	-.0632162	-.0096388

GDP growth (k^{*} / k)

```
. reg  lngdpgrowthratio lny lndeflatorratio lnemploymentratio,r

Linear regression                                      Number of obs =      30
                                                       F(  3,    26) =   23.18
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.5976
                                                       Root MSE      =  .00466
```

lngdpgrowt~o	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lny	.0298374	.0114819	2.60	0.015	.006236	.0534389
lndeflator~o	-.1419909	.0239373	-5.93	0.000	-.1911947	-.092787
lnemployme~o	.1884665	.0464721	4.06	0.000	.0929418	.2839913
_cons	.0209455	.0025283	8.28	0.000	.0157485	.0261426

GDP growth (k^{**} / k)

```
. reg  lngdpgrowthratio lny1 lndeflatorratio lnemploymentratio,r

Linear regression                                      Number of obs =      30
                                                       F(  3,    26) =   24.39
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.5640
                                                       Root MSE      =  .00485
```

lngdpgrowt~o	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lny1	.0307959	.0128417	2.40	0.024	.0043994	.0571925
lndeflator~o	-.1301456	.0208472	-6.24	0.000	-.1729977	-.0872936
lnemployme~o	.1759527	.0499154	3.53	0.002	.0733501	.2785553
_cons	.0261759	.0013324	19.65	0.000	.0234372	.0289146

Panel Regression Output

- *AUS NZL (panel)*

Inflation (k^* / k)

```
. xtreg  lndeflatorratio lny lnemploymentratio lngdpgrowthratio,r

Random-effects GLS regression                   Number of obs      =        60
Group variable: panelvar                        Number of groups   =         2

R-sq:  within  = 0.3077                         Obs per group: min =        30
       between = 1.0000                                        avg =      30.0
       overall = 0.3128                                        max =        30

Random effects u_i ~ Gaussian                   Wald chi2(3)       =     47.63
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000

                              (Std. Err. adjusted for clustering on panelvar)
------------------------------------------------------------------------------
             |               Robust
lndeflator~o |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         lny |   .0167853   .0158865     1.06   0.291    -.0143518    .0479223
lnemployme~o |   .4645563   .1072703     4.33   0.000     .2543103    .6748023
lngdpgrowt~o |  -2.111402   .7125084    -2.96   0.003    -3.507892    -.714911
       _cons |   .0763804   .0168583     4.53   0.000     .0433387    .1094222
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |  .03419776
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

Inflation (k^{**} / k)

```
. xtreg  lndeflatorratio lny1 lnemploymentratio lngdpgrowthratio,r

Random-effects GLS regression                   Number of obs      =        60
Group variable: panelvar                        Number of groups   =         2

R-sq:  within  = 0.3702                         Obs per group: min =        30
       between = 1.0000                                        avg =      30.0
       overall = 0.3688                                        max =        30

Random effects u_i ~ Gaussian                   Wald chi2(3)       =     56.08
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000

                              (Std. Err. adjusted for clustering on panelvar)
------------------------------------------------------------------------------
             |               Robust
lndeflator~o |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        lny1 |   .0260713   .0102349     2.55   0.011     .0060112    .0461315
lnemployme~o |   .4305031   .1101815     3.91   0.000     .2145513    .6464548
lngdpgrowt~o |    -2.1384   .6169249    -3.47   0.001    -3.347551   -.9292494
       _cons |   .0880325   .0151583     5.81   0.000     .0583227    .1177423
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |  .03250029
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

- *AUS (regression)*

Employment (k^* / k)

```
. reg  lnemploymentratio lny lndeflatorratio lngdpgrowthratio,r

Linear regression                                      Number of obs =      30
                                                       F(  3,    26) =    2.60
                                                       Prob > F      =  0.0733
                                                       R-squared     =  0.1954
                                                       Root MSE      =  .01501
```

lnemployme~o	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lny	.0317279	.0177503	1.79	0.086	-.0047584	.0682142
lndeflator~o	.308395	.117657	2.62	0.014	.0665475	.5502425
lngdpgrowt~o	.90875	.4057264	2.24	0.034	.0747673	1.742733
_cons	-.0013752	.0087178	-0.16	0.876	-.0192948	.0165444

Employment (k^{**} / k)

```
. reg  lnemploymentratio lny1 lndeflatorratio lngdpgrowthratio,r

Linear regression                                      Number of obs =      30
                                                       F(  3,    26) =    2.83
                                                       Prob > F      =  0.0578
                                                       R-squared     =  0.2142
                                                       Root MSE      =  .01483
```

lnemployme~o	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
lny1	.0308981	.0153271	2.02	0.054	-.0006072	.0624034
lndeflator~o	.2873844	.1093107	2.63	0.014	.0626931	.5120757
lngdpgrowt~o	.9440134	.4057969	2.33	0.028	.109886	1.778141
_cons	.0036387	.0075412	0.48	0.633	-.0118624	.0191399

-

GDP growth (k^* / k)

```
. xtreg  lngdpgrowthratio lny lndeflatorratio lnemploymentratio,r

Random-effects GLS regression                   Number of obs      =        60
Group variable: panelvar                        Number of groups   =         2

R-sq:  within  = 0.2593                         Obs per group: min =        30
       between = 1.0000                                        avg =      30.0
       overall = 0.3227                                        max =        30

Random effects u_i ~ Gaussian                   Wald chi2(3)       =     38.02
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000

                              (Std. Err. adjusted for clustering on panelvar)
```

lngdpgrowt~o	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
lny	.0094941	.0057052	1.66	0.096	-.0016879	.0206761
lndeflator~o	-.1175781	.0244166	-4.82	0.000	-.1654338	-.0697223
lnemployme~o	.077986	.0371355	2.10	0.036	.0052018	.1507703
_cons	.0231041	.0026896	8.59	0.000	.0178326	.0283756
sigma_u	0					
sigma_e	.0078984					
rho	0	(fraction of variance due to u_i)				

GDP growth (k^{**} / k)

```
. xtreg  lngdpgrowthratio lny1 lndeflatorratio lnemploymentratio,r

Random-effects GLS regression                   Number of obs      =        60
Group variable: panelvar                        Number of groups   =         2

R-sq:  within  = 0.2478                         Obs per group: min =        30
       between = 1.0000                                        avg =      30.0
       overall = 0.3122                                        max =        30

Random effects u_i ~ Gaussian                   Wald chi2(3)       =     34.20
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000

                              (Std. Err. adjusted for clustering on panelvar)
------------------------------------------------------------------------------
             |               Robust
lngdpgrowt~o |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        lny1 |   .0058092   .0041931     1.39   0.166    -.0024092    .0140276
lndeflator~o |  -.1316844    .024494    -5.38   0.000    -.1796917   -.0836771
lnemployme~o |   .0856071   .0389456     2.20   0.028      .009275    .1619391
       _cons |   .0234053   .0031066     7.53   0.000     .0173166    .0294941
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |  .00794267
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

- *CAN MEX USA (panel)*

Inflation (k^{*} / k)

```
. xtreg  lndeflatorratio lny lngdpgrowthratio,r

Random-effects GLS regression                   Number of obs      =        90
Group variable: panelvar                        Number of groups   =         3

R-sq:  within  = 0.2345                         Obs per group: min =        30
       between = 0.9301                                        avg =      30.0
       overall = 0.3921                                        max =        30

Random effects u_i ~ Gaussian                   Wald chi2(2)       =     28.48
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000

                              (Std. Err. adjusted for clustering on panelvar)
------------------------------------------------------------------------------
             |               Robust
lndeflator~o |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         lny |  -.0252394   .0337866    -0.75   0.455      -.09146    .0409811
lngdpgrowt~o |  -10.26512   2.554174    -4.02   0.000     -15.2712   -5.259027
       _cons |   .2427913   .0478343     5.08   0.000     .1490377    .3365449
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |  .08242443
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

Inflation (k^{**} / k)

```
. xtreg  lndeflatorratio lny1  lngdpgrowthratio,r

Random-effects GLS regression                   Number of obs      =        90
Group variable: panelvar                        Number of groups   =         3

R-sq:  within  = 0.2471                         Obs per group: min =        30
       between = 0.9164                                        avg =      30.0
       overall = 0.3904                                        max =        30

Random effects u_i ~ Gaussian                   Wald chi2(2)       =     28.03
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000

                                 (Std. Err. adjusted for clustering on panelvar)
------------------------------------------------------------------------------
             |               Robust
lndeflator~o |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        lny1 |  -.0139274   .0309925    -0.45   0.653    -.0746716    .0468168
lngdpgrowt~o |  -10.40785   2.533867    -4.11   0.000    -15.37414   -5.441561
       _cons |   .2432125   .0513647     4.74   0.000     .1425396    .3438854
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |  .08312401
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

Employment (k^{*} / k)

```
. xtreg  lnemploymentratio lny lndeflatorratio lngdpgrowthratio,r

Random-effects GLS regression                   Number of obs      =        90
Group variable: panelvar                        Number of groups   =         3

R-sq:  within  = 0.0177                         Obs per group: min =        30
       between = 0.6517                                        avg =      30.0
       overall = 0.0449                                        max =        30

Random effects u_i ~ Gaussian                   Wald chi2(3)       =      8.12
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0435

                                 (Std. Err. adjusted for clustering on panelvar)
------------------------------------------------------------------------------
             |               Robust
lnemployme~o |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         lny |  -.0121249   .0088581    -1.37   0.171    -.0294866    .0052367
lndeflator~o |   .0226239   .0158203     1.43   0.153    -.0083834    .0536311
lngdpgrowt~o |   .6091158   .2798653     2.18   0.030     .0605898    1.157642
       _cons |   .0046433   .0062252     0.75   0.456    -.0075578    .0168444
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |  .02611879
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

Employment (k^{**} / k)

```
. xtreg  lnemploymentratio lny1 lndeflatorratio lngdpgrowthratio,r

Random-effects GLS regression                   Number of obs      =        90
Group variable: panelvar                        Number of groups   =         3

R-sq:  within  = 0.0178                         Obs per group: min =        30
       between = 0.6568                                        avg =      30.0
       overall = 0.0450                                        max =        30

Random effects u_i ~ Gaussian                   Wald chi2(3)       =      7.89
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0484

                             (Std. Err. adjusted for clustering on panelvar)
------------------------------------------------------------------------------
             |               Robust
lnemployme~o |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        lny1 |  -.0108468   .0082994    -1.31   0.191    -.0271133    .0054198
lndeflator~o |   .0234778   .0159835     1.47   0.142    -.0078493    .0548049
lngdpgrowt~o |   .5963369   .2807847     2.12   0.034     .0460089    1.146665
       _cons |    .002501   .0062092     0.40   0.687    -.0096688    .0146709
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |  .02614708
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

GDP growth (k^{*} / k)

```
. xtreg  lngdpgrowthratio lny lndeflatorratio,r

Random-effects GLS regression                   Number of obs      =        90
Group variable: panelvar                        Number of groups   =         3

R-sq:  within  = 0.3332                         Obs per group: min =        30
       between = 0.8680                                        avg =      30.0
       overall = 0.4169                                        max =        30

Random effects u_i ~ Gaussian                   Wald chi2(2)       =     64.66
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000

                             (Std. Err. adjusted for clustering on panelvar)
------------------------------------------------------------------------------
             |               Robust
lngdpgrowt~o |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         lny |   .0045489   .0018955     2.40   0.016     .0008338    .0082639
lndeflator~o |  -.0343501   .0047012    -7.31   0.000    -.0435642   -.0251361
       _cons |   .0181292   .0008971    20.21   0.000     .0163709    .0198875
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |  .00686989
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

GDP growth (k^{**} / k)

```
. xtreg  lngdpgrowthratio lny1 lndeflatorratio ,r

Random-effects GLS regression                   Number of obs      =        90
Group variable: panelvar                        Number of groups   =         3

R-sq:  within  = 0.3177                         Obs per group: min =        30
       between = 0.8707                                        avg =      30.0
       overall = 0.4114                                        max =        30

Random effects u_i ~ Gaussian                   Wald chi2(2)       =     62.88
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000

                               (Std. Err. adjusted for clustering on panelvar)
------------------------------------------------------------------------------
             |               Robust
lngdpgrowt~o |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        lny1 |   .0036559    .001748     2.09   0.036     .0002299    .0070818
lndeflator~o |  -.0350507   .0047089    -7.44   0.000      -.04428   -.0258215
       _cons |   .0188922   .0010315    18.32   0.000     .0168705    .0209138
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |   .0070558
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

- *FRA GER (panel)*

Inflation (k^{*} / k)

```
. xtreg  lndeflatorratio lny lnemploymentratio lngdpgrowthratio,r

Random-effects GLS regression                   Number of obs      =        47
Group variable: panelvar                        Number of groups   =         2

R-sq:  within  = 0.0620                         Obs per group: min =        18
       between = 1.0000                                        avg =      23.5
       overall = 0.1516                                        max =        29

Random effects u_i ~ Gaussian                   Wald chi2(3)       =     11.71
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0084

                               (Std. Err. adjusted for clustering on panelvar)
------------------------------------------------------------------------------
             |               Robust
lndeflator~o |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         lny |   .0169498   .0083865     2.02   0.043     .0005125    .0333871
lnemployme~o |  -.7325967   .3096037    -2.37   0.018    -1.339409   -.1257845
lngdpgrowt~o |   1.742387   .6887078     2.53   0.011     .3925447     3.09223
       _cons |   .0056939   .0094328     0.60   0.546     -.012794    .0241818
-------------+----------------------------------------------------------------
     sigma_u |          0
    sigma_e |  .02159531
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

Inflation (k^{**} / k)

```
. xtreg  lndeflatorratio lny1 lnemploymentratio lngdpgrowthratio,r

Random-effects GLS regression                   Number of obs      =        47
Group variable: panelvar                        Number of groups   =         2

R-sq:  within  = 0.0607                         Obs per group: min =        18
       between = 1.0000                                        avg =      23.5
       overall = 0.1465                                        max =        29

Random effects u_i ~ Gaussian                   Wald chi2(3)       =     11.64
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0087

                               (Std. Err. adjusted for clustering on panelvar)
```

lndeflator~o	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
lny1	.0133096	.0067664	1.97	0.049	.0000477	.0265716
lnemployme~o	-.7270663	.3107471	-2.34	0.019	-1.336119	-.1180131
lngdpgrowt~o	1.797726	.6882546	2.61	0.009	.448772	3.14668
_cons	.0074113	.009743	0.76	0.447	-.0116845	.0265072
sigma_u	0					
sigma_e	.02160098					
rho	0	(fraction of variance due to u_i)				

Employment (k^{*} / k)

```
. xtreg  lnemploymentratio lny lndeflatorratio lngdpgrowthratio,r

Random-effects GLS regression                   Number of obs      =        47
Group variable: panelvar                        Number of groups   =         2

R-sq:  within  = 0.2250                         Obs per group: min =        18
       between = 1.0000                                        avg =      23.5
       overall = 0.2294                                        max =        29

Random effects u_i ~ Gaussian                   Wald chi2(3)       =     22.79
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000

                               (Std. Err. adjusted for clustering on panelvar)
```

lnemployme~o	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
lny	.0120842	.0038526	3.14	0.002	.0045332	.0196353
lndeflator~o	-.134342	.0402632	-3.34	0.001	-.2132564	-.0554276
lngdpgrowt~o	.6864708	.3980982	1.72	0.085	-.0937873	1.466729
_cons	-.0004732	.0061627	-0.08	0.939	-.0125519	.0116054
sigma_u	0					
sigma_e	.00939172					
rho	0	(fraction of variance due to u_i)				

Employment (k^{**} / k)

```
. xtreg  lnemploymentratio lny1 lndeflatorratio lngdpgrowthratio,r

Random-effects GLS regression                   Number of obs      =        47
Group variable: panelvar                        Number of groups   =         2

R-sq:  within  = 0.2281                         Obs per group: min =        18
       between = 1.0000                                        avg =      23.5
       overall = 0.2320                                        max =        29

Random effects u_i ~ Gaussian                   Wald chi2(3)       =     24.55
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000

                              (Std. Err. adjusted for clustering on panelvar)
------------------------------------------------------------------------------
             |               Robust
lnemployme~o |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        lny1 |   .0101658   .0030417     3.34   0.001     .0042041    .0161274
lndeflator~o |   -.132089   .0402568    -3.28   0.001    -.2109908   -.0531872
lngdpgrowt~o |   .7123142   .4006363     1.78   0.075    -.0729184    1.497547
       _cons |   .0011333   .0063124     0.18   0.858    -.0112388    .0135054
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |  .00953385
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

GDP growth (k^{*} / k)

```
. xtreg  lngdpgrowthratio lny lndeflatorratio lnemploymentratio,r

Random-effects GLS regression                   Number of obs      =        47
Group variable: panelvar                        Number of groups   =         2

R-sq:  within  = 0.0535                         Obs per group: min =        18
       between = 1.0000                                        avg =      23.5
       overall = 0.1193                                        max =        29

Random effects u_i ~ Gaussian                   Wald chi2(3)       =      9.20
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0267

                              (Std. Err. adjusted for clustering on panelvar)
------------------------------------------------------------------------------
             |               Robust
lngdpgrowt~o |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         lny |   .0007342   .0014512     0.51   0.613      -.00211    .0035785
lndeflator~o |   .0346504   .0170831     2.03   0.043     .0011681    .0681327
lnemployme~o |   .0744456   .0418082     1.78   0.075    -.0074969    .1563881
       _cons |   .0127445   .0008614    14.80   0.000     .0110562    .0144327
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |  .00326581
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

GDP growth (k^{**} / k)

```
. xtreg  lngdpgrowthratio lny1 lndeflatorratio lnemploymentratio,r

Random-effects GLS regression                   Number of obs      =        47
Group variable: panelvar                        Number of groups   =         2

R-sq:  within  = 0.0561                         Obs per group: min =        18
       between = 1.0000                                        avg =      23.5
       overall = 0.1168                                        max =        29

Random effects u_i ~ Gaussian                   Wald chi2(3)       =      8.95
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0299

                             (Std. Err. adjusted for clustering on panelvar)
------------------------------------------------------------------------------
             |               Robust
lngdpgrowt~o |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        lny1 |   .0003796   .0012178     0.31   0.755    -.0020073    .0027665
lndeflator~o |   .0356371   .0169549     2.10   0.036      .002406    .0688681
lnemployme~o |   .0777244   .0420201     1.85   0.064    -.0046335    .1600823
       _cons |   .0127471   .0010406    12.25   0.000     .0107076    .0147867
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |   .0032023
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

Appendix 6.2

General Regression and Panel Regression Equations for the Economies

GENERAL EQUATIONS (Regression)	**ASIA (JPN)**	**ASIA (KOR)**	**EUROPE 2 (UK)**	**PACIFIC (AUS)**
Inflation, P	$Ln(\pi) = -0.015 + 0.018ln(k^{*}/k) + 0.624ln(GDP)$	$Ln(\pi) = 0.045 + 0.157ln(k^{*}/k) – 2.324ln(GDP)$	$Ln(\pi) = 0.069 + 0.187ln(k^{*}/k) + 0.432ln(N) – 3.037ln(GDP)$	N.A.
	$Ln(\pi) = -0.013 + 0.016ln(k^{**}/k) + 0.631ln(GDP)$	$Ln(\pi) = 0.077 + 0.155ln(k^{**}/k) – 2.546ln(GDP)$	$Ln(\pi) = 0.096 + 0.199ln(k^{**}/k) – 2.548ln(GDP)$	N.A.
Employment, N	$Ln(N) = -0.006 + 0.015ln(k^{*}/k) + 0.349ln(GDP)$	$Ln(N) = -0.0008 + 0.027ln(k^{*}/k) – 0.010ln(\pi)$	$Ln(N) = -0.030 – 0.063ln(k^{*}/k) + 0.191ln(\pi) + 1.779ln(GDP)$	$Ln(N) = -0.001 + 0.0317ln(k^{*}/k) + 0.308ln(\pi) + 0.909ln(GDP)$
	$Ln(N) = -0.005 + 0.015ln(k^{**}/k) + 0.349ln(GDP)$	$Ln(N) = 0.004 + 0.025ln(k^{**}/k) – 0.096ln(\pi)$	$Ln(N) = -0.036 – 0.053 ln(k^{**}/k) + 0.129ln(\pi) + 1.649ln(GDP)$	$Ln(N) = 0.004 + 0.0309ln(k^{**}/k) + 0.287ln(\pi) + 0.944ln(GDP)$
GDP per capita, GDP	$Ln(GDP) = 0.016 – 0.003ln(k^{*}/k) + 0.511ln(\pi) + 0.578ln(N)$	$Ln(GDP) = 0.018 + 0.047ln(k^{*}/k) – 0.060ln(\pi)$	$Ln(GDP) = 0.021 + 0.030ln(k^{*}/k) – 0.142ln(\pi) + 0.188ln(N)$	N.A.
	$Ln(GDP) = 0.016 – 0.002ln(k^{**}/k) + 0.506ln (\pi) + 0.567ln(N)$	$Ln(GDP) = 0.025 + 0.044ln(k^{**}/k) – 0.056ln(\pi)$	$Ln(GDP) = 0.026 + 0.031ln(k^{**}/k) – 0.130ln(\pi) + 0.176ln(N)$	N.A.

Table 6.5: General Regression Equations for Japan, Korea, and United Kingdom

GENERAL EQUATIONS (Panel)	**PACIFIC (AUS, NZL)**	**AMERICAS (CAN, MEX, USA)**	**EUROPE 1 (FRA, GER)**
Inflation, P	$Ln(\pi) = 0.076 + 0.017ln(k^{*}/k) + 0.465ln(N) – 2.111ln(GDP)$	$Ln(\pi) = 0.243 – 0.025ln(k^{*}/k) – 10.27ln(GDP)$	$Ln(\pi) = 0.006 + 0.017ln(k^{*}/k) – 0.733ln(N) + 1.742ln(GDP)$
	$Ln(\pi) = 0.088 + 0.026ln(k^{**}/k) + 0.431ln(N) – 2.138ln(GDP)$	$Ln(\pi) = 0.243 – 0.014ln(k^{**}/k) – 10.41ln(GDP)$	$Ln(\pi) = 0.007 + 0.013ln(k^{**}/k) – 0.727ln(N) + 1.798ln(GDP)$
Employment, N	$Ln(N) = - 0.005 + 0.010ln(k^{*}/k) + 0.307ln(\pi) + 0.924ln(GDP)$	$Ln(N) = 0.005 – 0.012ln(k^{*}/k) + 0.023ln(\pi) + 0.609ln(GDP)$	$Ln(N) = - 0.0005 + 0.012ln(k^{*}/k) – 0.134ln(\pi) + 0.686ln(GDP)$
	$Ln(N) = -0.010 + 0.002ln(k^{**}/k) + 0.312ln(\pi) + 1.007ln(GDP)$	$Ln(N) = 0.003 – 0.011ln(k^{**}/k) + 0.023ln(\pi) + 0.596ln(GDP)$	$Ln(N) = 0.001 + 0.010ln(k^{**}/k) – 0.132ln(\pi) + 0.712ln(GDP)$
GDP per capita, GDP	$Ln(GDP) = 0.023 + 0.009ln(k^{*}/k) – 0.118ln(\pi) + 0.078ln(N)$	$Ln(GDP) = 0.018 + 0.005ln(k^{*}/k) – 0.034ln(\pi)$	$Ln(GDP) = 0.013 + 0.0007ln(k^{*}/k) + 0.035ln(\pi) + 0.074ln(N)$
	$Ln(GDP) = 0.023 + 0.006ln(k^{**}/k) – 0.132ln(\pi) + 0.086ln(N)$	$Ln(GDP) = 0.019 + 0.004ln(k^{**}/k) – 0.035ln(\pi)$	$Ln(GDP) = 0.013 + 0.0004ln(k^{**}/k) + 0.036ln(\pi) + 0.078ln(N)$

Table 6.6: General Panel Regression Equations for Australia, New Zealand, Canada, Mexico, the USA, France and Germany

GENERAL EQUATIONS (2009)	**ASIA (JAP) Regression**	**ASIA (KOR) Regression**
Inflation, P	$Ln(\pi) = -0.013 + 0.018ln(k^{*}/k)$	$Ln(\pi) = -0.025 + 0.157ln(k^{*}/k)$
	$Ln(\pi) = -0.01 + 0.016ln(k^{**}/k)$	$Ln(\pi) = 0.0006 + 0.155ln(k^{**}/k)$
Employment, N	$Ln(N) = -0.005 + 0.015ln(k^{*}/k)$	$Ln(N) = 0.001 + 0.027ln(k^{*}/k)$
	$Ln(N) = -0.004 + 0.015ln(k^{**}/k)$	$Ln(N) = 0.001 + 0.025ln(k^{**}/k)$
GDP per capita, GDP	$Ln(GDP) = 0.004 – 0.003ln(k^{*}/k)$	$Ln(GDP) = 0.016 + 0.047ln(k^{*}/k)$
	$Ln(GDP) = 0.004 – 0.002ln(k^{**}/k)$	$Ln(GDP) = 0.023 + 0.044ln(k^{**}/k)$

Table 6.7: 2009 Equations for Japan and Korea from Regression Analysis

GENERAL EQUATIONS (2009)	EUROPE 2 (UK) Regression
Inflation, P	$Ln(\pi) = 0.036 + 0.187ln(k^{*}/k)$
	$Ln(\pi) = 0.076 + 0.199ln(k^{**}/k)$
Employment, N	$Ln(N) = 0.047 - 0.063ln(k^{*}/k)$
	$Ln(N) = -0.021 – 0.053ln(k^{**}/k)$
GDP per capita, GDP	$Ln(GDP) = 0.015 + 0.030ln(k^{*}/k)$
	$Ln(GDP) = 0.020 + 0.031ln(k^{**}/k)$

Table 6.8: 2009 Equations for the United Kingdom from Regression Analysis

GENERAL EQUATIONS (2009)	PACIFIC (AUS) Panel	PACIFIC (NZL) Panel
Inflation, P	$Ln(\pi) = 0.067 + 0.017ln(k^{*}/k)$	$Ln(\pi) = 0.052 + 0.017ln(k^{*}/k)$
	$Ln(\pi) = 0.079 + 0.026ln(k^{**}/k)$	$Ln(\pi) = 0.064 + 0.026ln(k^{**}/k)$
Employment, N	$Ln(N) = 0.004 + 0.0317ln(k^{*}/k)$ *(Regression)*	$Ln(N) = 0.005 + 0.010ln(k^{*}/k)$
	$Ln(N) = 0.009 +0.0309ln(k^{**}/k)$ *(Regression)*	$Ln(N) = 0.0003 + 0.002ln(k^{**}/k)$
GDP per capita, GDP	$Ln(GDP) = 0.023 + 0.009ln(k^{*}/k)$	$Ln(GDP) = 0.022 + 0.009ln(k^{*}/k)$
	$Ln(GDP) = 0.023 + 0.006ln(k^{**}/k)$	$Ln(GDP) = 0.022 + 0.006ln(k^{**}/k)$

Table 6.9: 2009 Equations for Australia and New Zealand

from Panel Regression Analysis

GENERAL EQUATIONS (2009)	**AMERICAS (CAN) Panel**	**AMERICAS (MEX) Panel**	**AMERICAS (USA) Panel**
Inflation, P	$Ln(\pi) = 0.192 - 0.025ln(k^*/k)$	$Ln(\pi) = 0.161 - 0.025ln(k^*/k)$	$Ln(\pi) = 0.222 - 0.025ln(k^*/k)$
	$Ln(\pi) = 0.191 - 0.014ln(k^{**}/k)$	$Ln(\pi) = 0.161 - 0.014ln(k^{**}/k)$	$Ln(\pi) = 0.222 - 0.014ln(k^{**}/k)$
Employment, N	$Ln(N) = 0.008 - 0.012ln(k^*/k)$	$Ln(N) = 0.011 - 0.012ln(k^*/k)$	$Ln(N) = 0.006 - 0.012ln(k^*/k)$
	$Ln(N) = 0.002 - 0.011ln(k^{**}/k)$	$Ln(N) = 0.009 - 0.011\ ln(k^{**}/k)$	$Ln(N) = 0.004 - 0.011\ ln(k^{**}/k)$
GDP per capita, GDP	$Ln(GDP) = 0.019 + 0.005ln(k^*/k)$	$Ln(GDP) = 0.017 + 0.005ln(k^*/k)$	$Ln(GDP) = 0.018 + 0.005ln(k^*/k)$
	$Ln(GDP) = 0.020 + 0.004ln(k^{**}/k)$	$Ln(GDP) = 0.018 + 0.004ln(k^{**}/k)$	$Ln(GDP) = 0.019 + 0.004ln(k^{**}/k)$

Table 6.10: 2009 Equations for Canada, Mexico, and the USA

from Panel Regression Analysis

GENERAL EQUATIONS (2009)	**EUROPE 1 (FRA) Panel**	**EUROPE 2 (GER) Panel**
Inflation, P	$Ln(\pi) = 0.025 + 0.017ln(k^{*}/k)$	$Ln(\pi) = 0.022 + 0.017ln(k^{*}/k)$
	$Ln(\pi) = 0.027 + 0.013ln(k^{**}/k)$	$Ln(\pi) = 0.026 + 0.013ln(k^{**}/k)$
Employment, N	$Ln(N) = 0.003 + 0.012ln(k^{*}/k)$	$Ln(N) = 0.005 + 0.012ln(k^{*}/k)$
	$Ln(N) = 0.005 + 0.010ln(k^{**}/k)$	$Ln(N) = 0.007 + 0.010ln(k^{**}/k)$
GDP per capita, GDP	$Ln(GDP) = 0.012 + 0.0007ln(k^{*}/k)$	$Ln(GDP) = 0.013 + 0.0007ln(k^{*}/k)$
	$Ln(GDP) = 0.012 + 0.0004ln(k^{**}/k)$	$Ln(GDP) = 0.013 + 0.0004ln(k^{**}/k)$

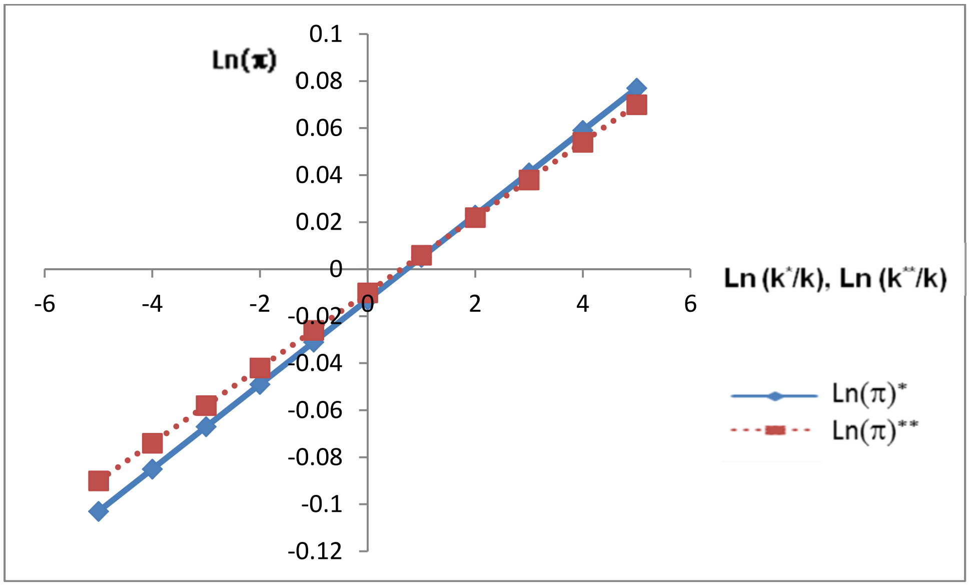
Table 6.11: 2009 Equations for France and Germany from Panel Regression Analysis

Appendix 6.3

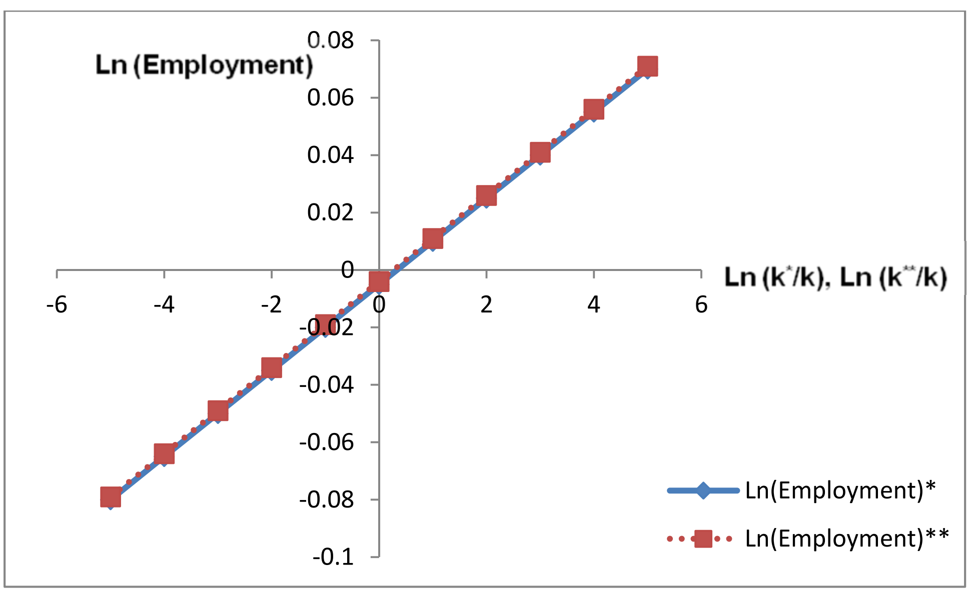
2009 Snapshots of the Macroeconomic Variables for the Economies

- JAP

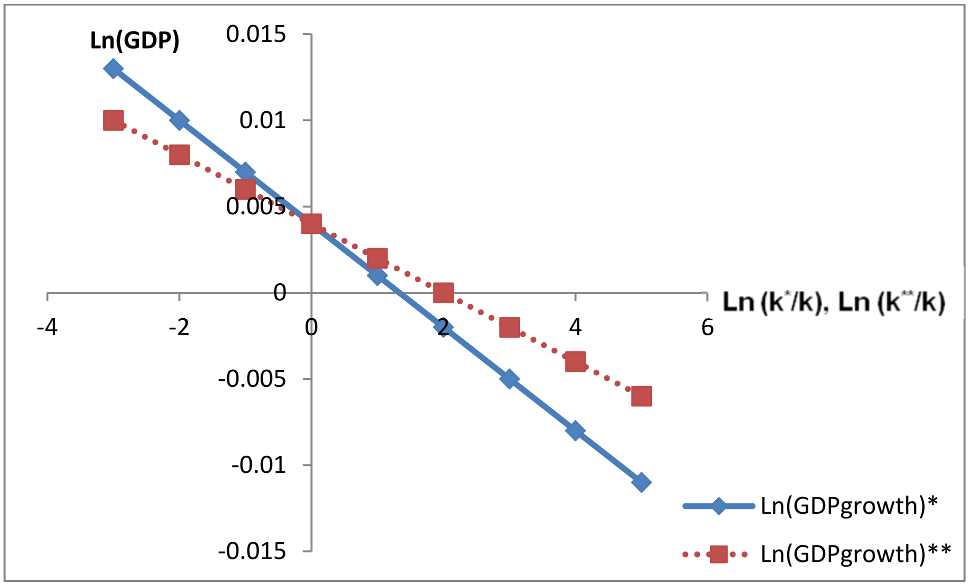
$Ln(\pi) = -0.013 + 0.018\ ln(k^{*}/k)$, $Ln(\pi) = -0.010 + 0.016\ ln(k^{**}/k)$



$Ln(N) = -0.005 + 0.015\ ln(k^{*}/k)$, $Ln(N) = -0.004 + 0.015\ ln(k^{**}/k)$

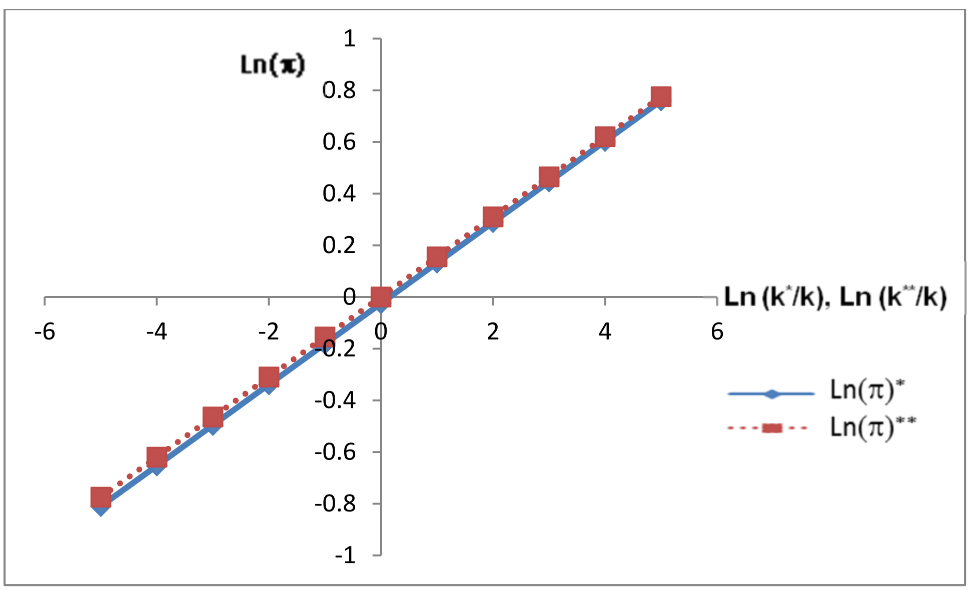


$Ln(GDP) = 0.004 – 0.003ln(k^{*}/k)$, $Ln(GDP) = 0.004 – 0.002ln(k^{**}/k)$

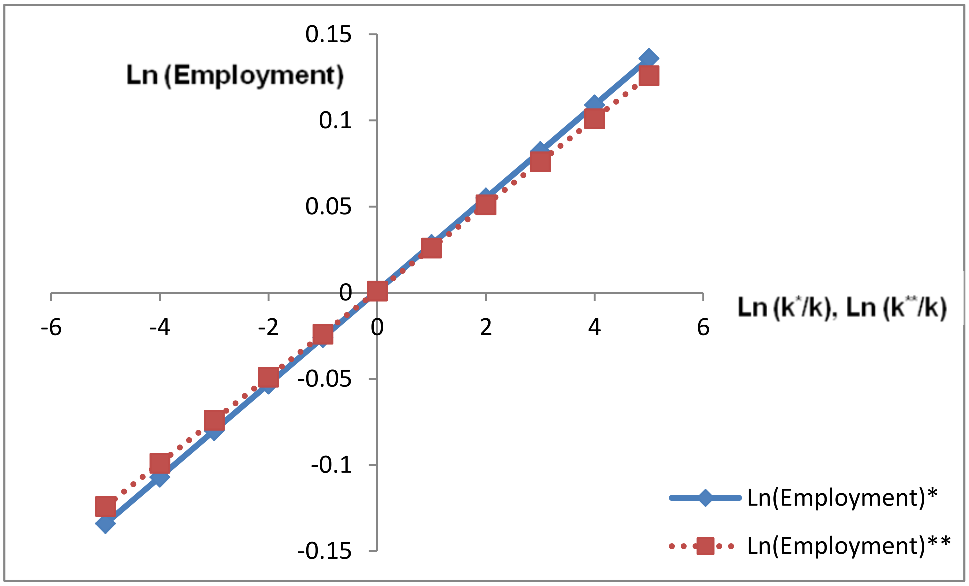


- KOR

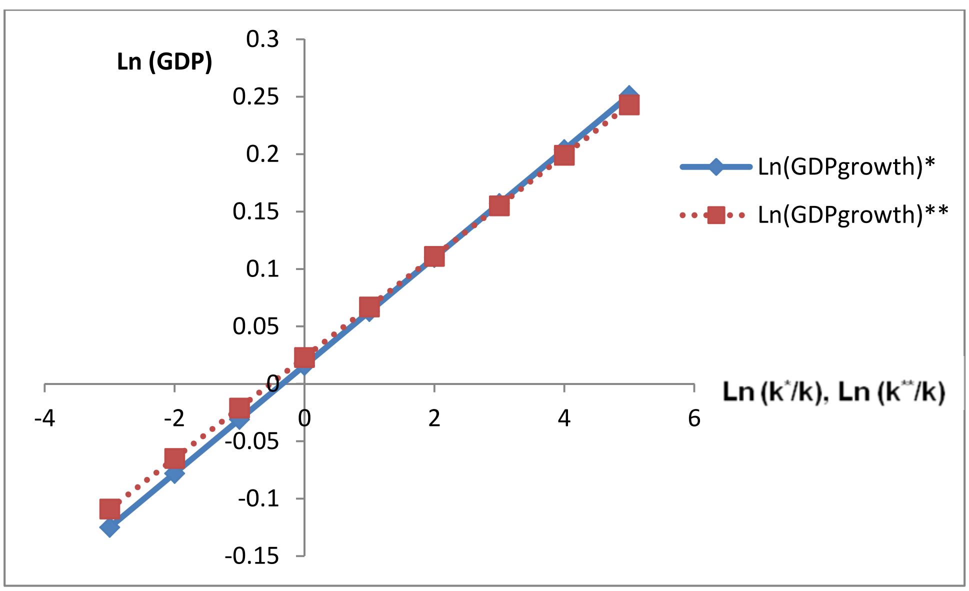
$Ln(\pi) = -0.025 + 0.157 \ln(k^{*}/k)$, $Ln(\pi) = 0.0006 + 0.155 \ln(k^{**}/k)$



$Ln(N) = 0.001 + 0.027 \ln(k^{*}/k)$, $Ln(N) = 0.001 + 0.025 \ln(k^{**}/k)$

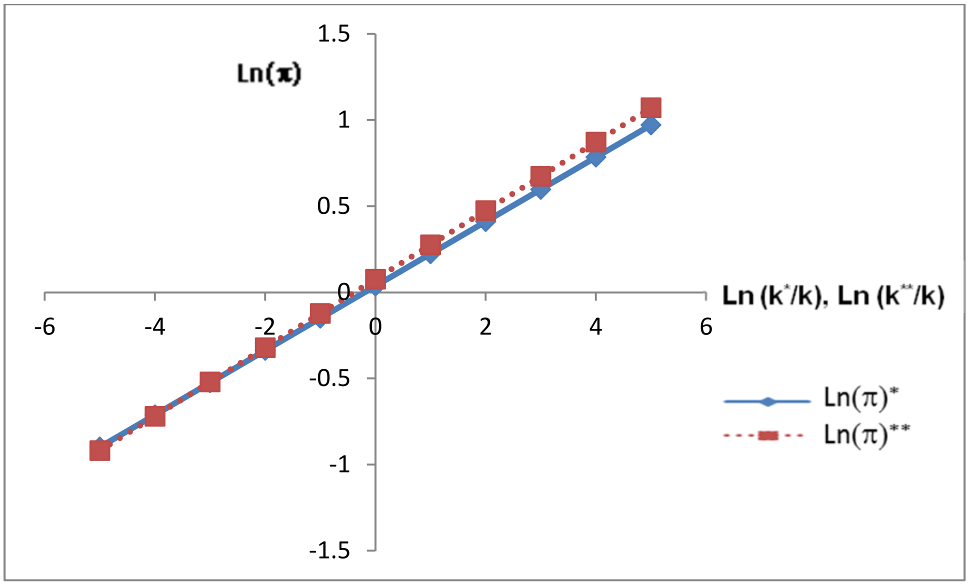


$Ln(GDP) = 0.016 + 0.047 \ln(k^{*}/k)$, $Ln(GDP) = 0.023 + 0.044 \ln(k^{**}/k)$

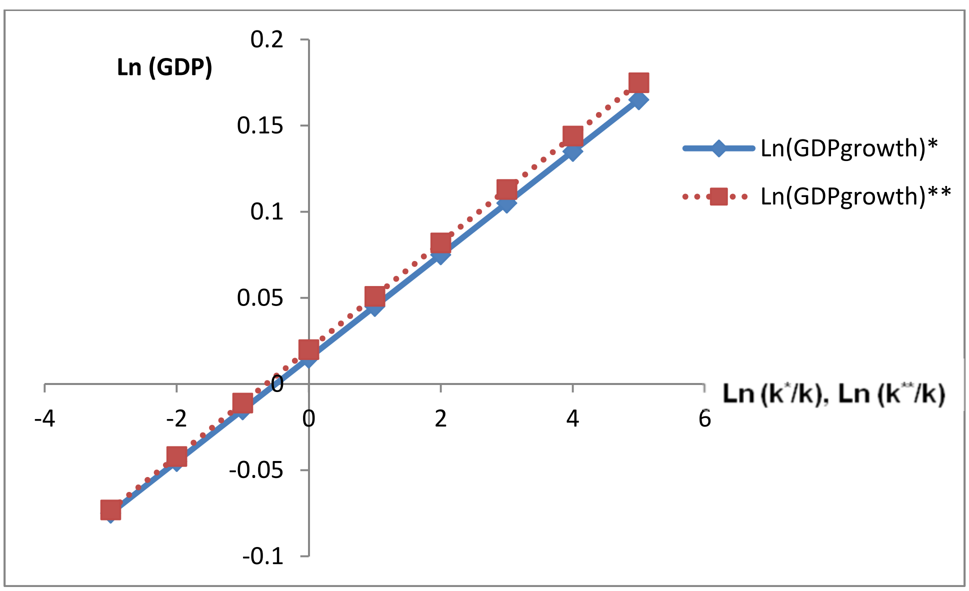


- UK

$Ln(\pi) = 0.036 + 0.187\ ln(k^{*}/k)$, $Ln(\pi) = 0.076 + 0.199\ ln(k^{**}/k)$

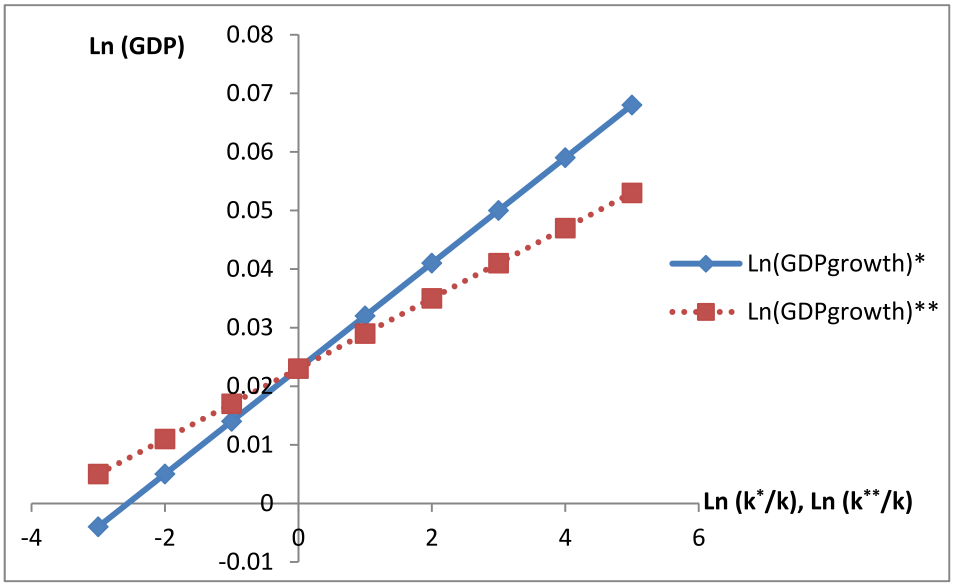


$Ln(GDP) = 0.015 + 0.030\ ln(k^{*}/k)$, $Ln(GDP) = 0.020 + 0.031\ ln(k^{**}/k)$



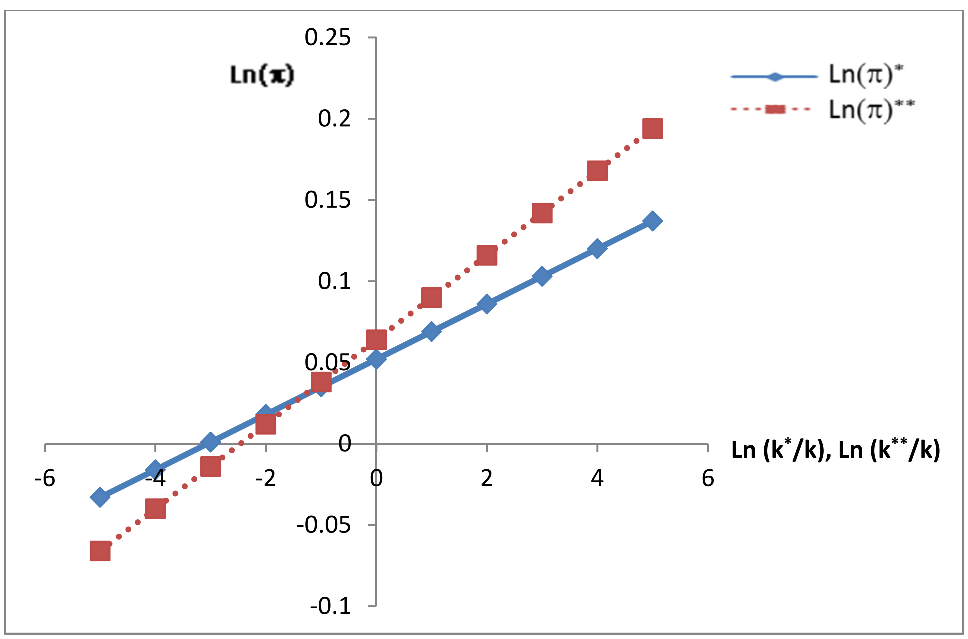
▪ AUS

$Ln(GDP) = 0.023 + 0.009 \ln(k^{*}/k)$, $Ln(GDP) = 0.023 + 0.006 \ln(k^{**}/k)$

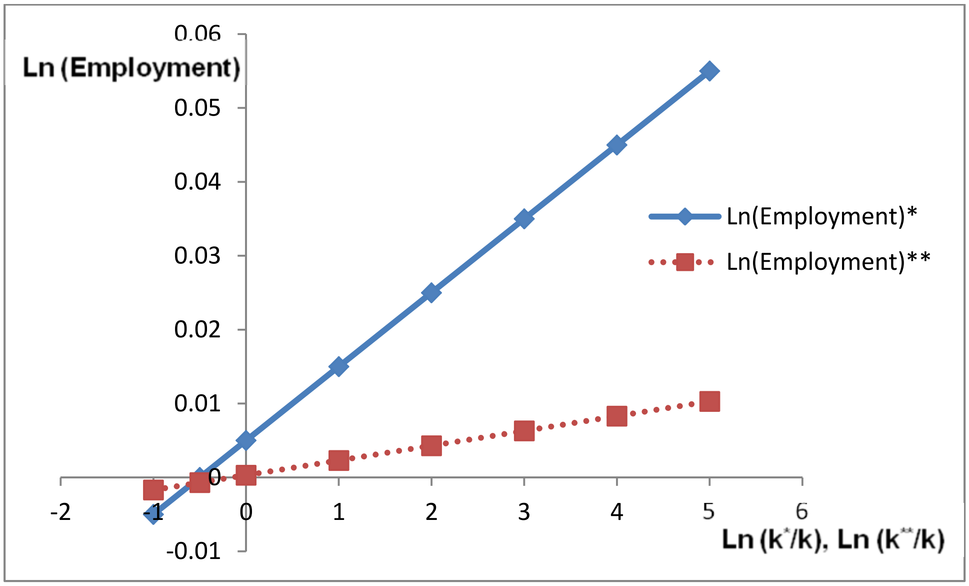


▪ NZL

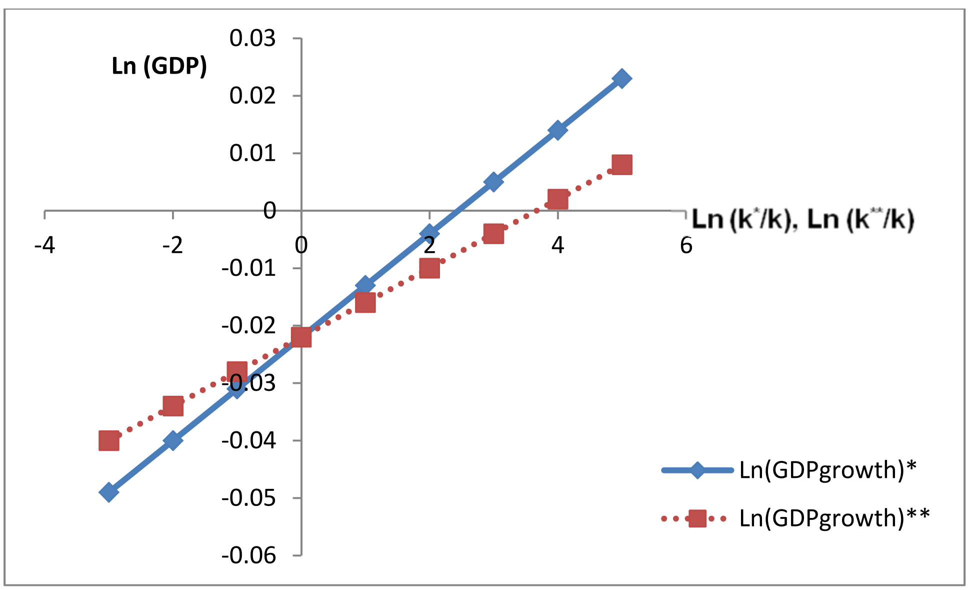
$Ln(\pi) = 0.052 + 0.017 \ln(k^{*}/k)$, $Ln(\pi) = 0.064 + 0.026 \ln(k^{**}/k)$



$\text{Ln(N)} = 0.005 + 0.010\ \ln(k^{*}/k)$, $\text{Ln(N)} = 0.0003 + 0.002\ \ln(k^{**}/k)$

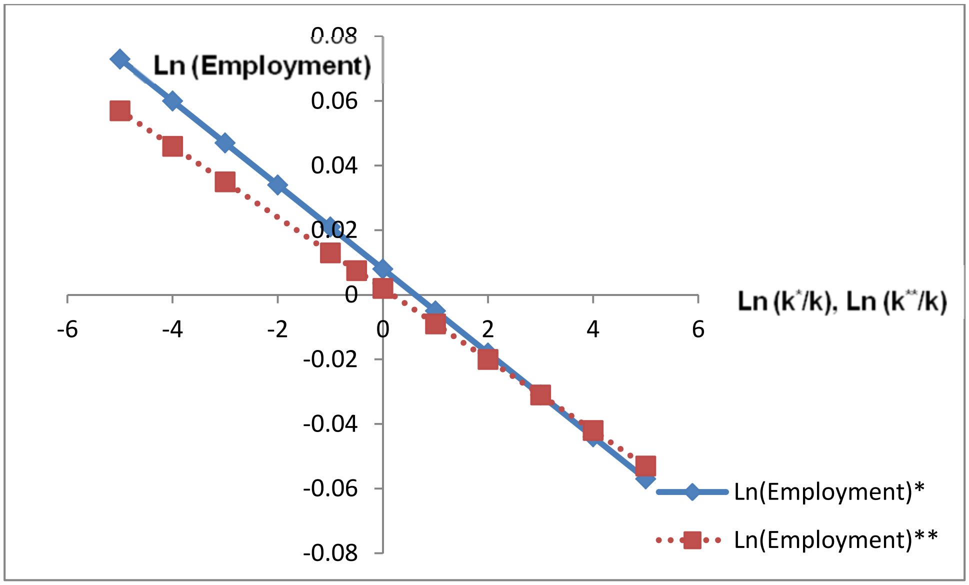


$\text{Ln(GDP)} = 0.022 + 0.009\ \ln(k^{*}/k)$, $\text{Ln(GDP)} = 0.022 + 0.006\ \ln(k^{**}/k)$

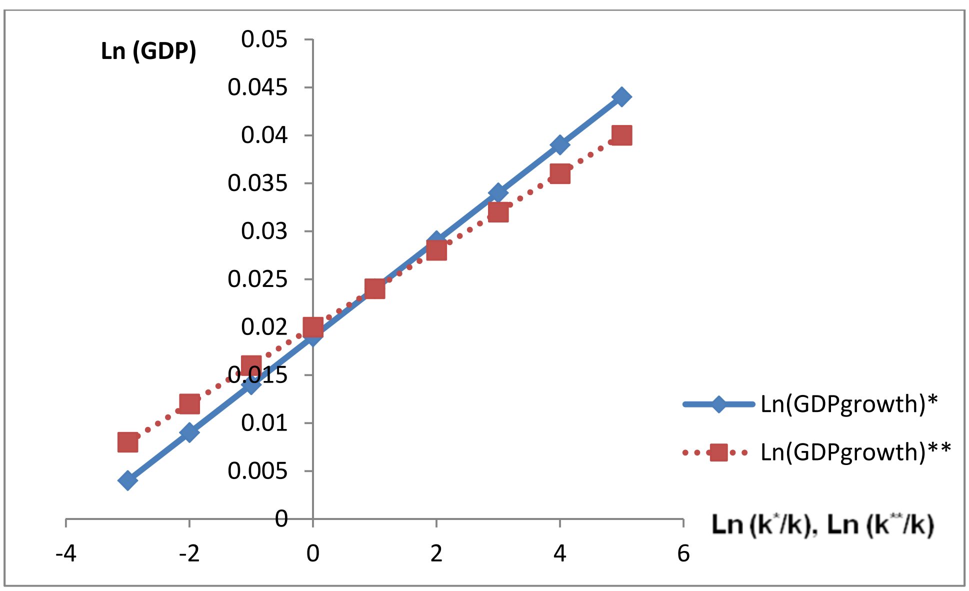


- CAN

Ln(N) = 0.008 – 0.013 ln(k^*/k), Ln(N) = 0.002 – 0.011 ln(k^{**}/k)

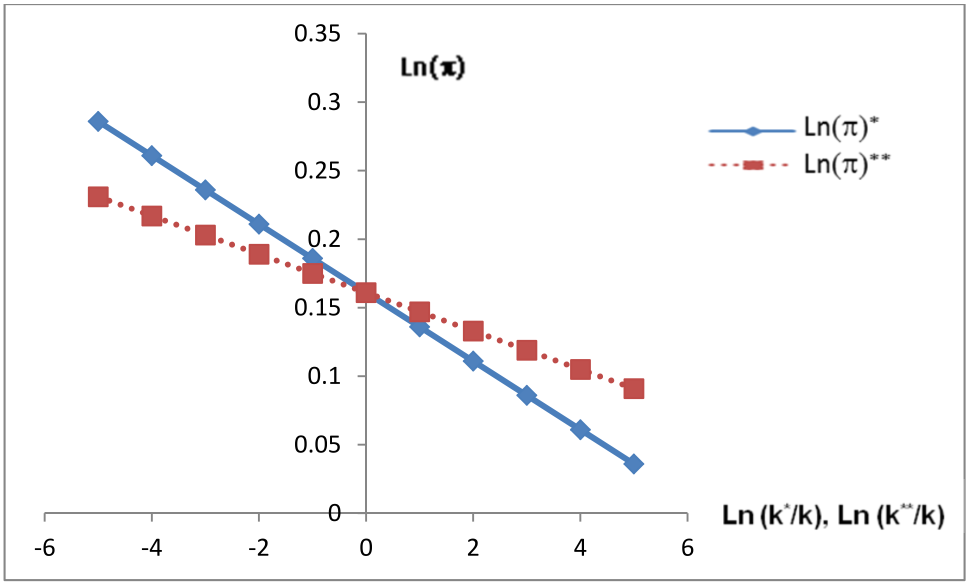


Ln(GDP) = 0.019 + 0.005 ln(k^*/k), Ln(GDP) = 0.020 + 0.004 ln(k^{**}/k)

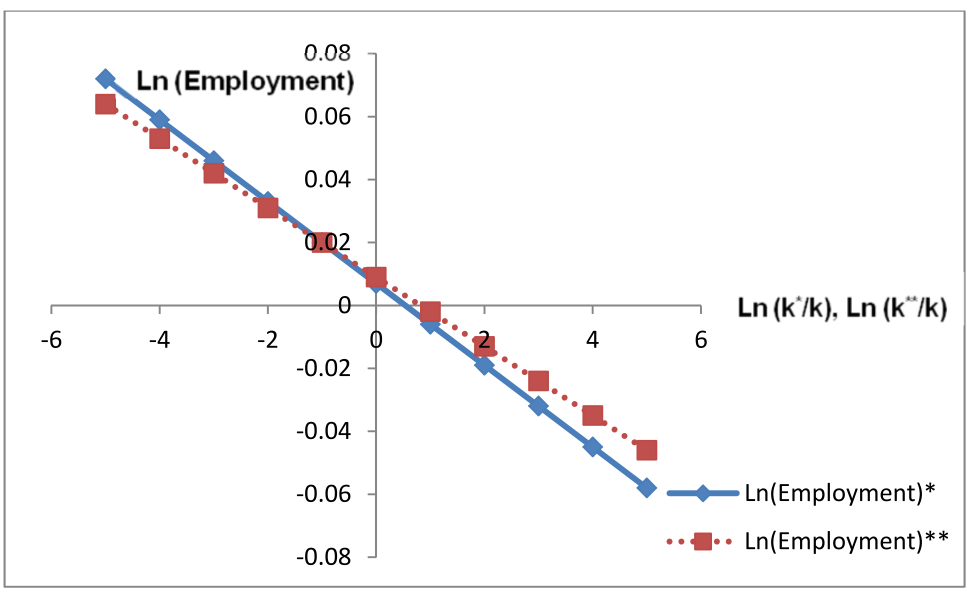


- MEX

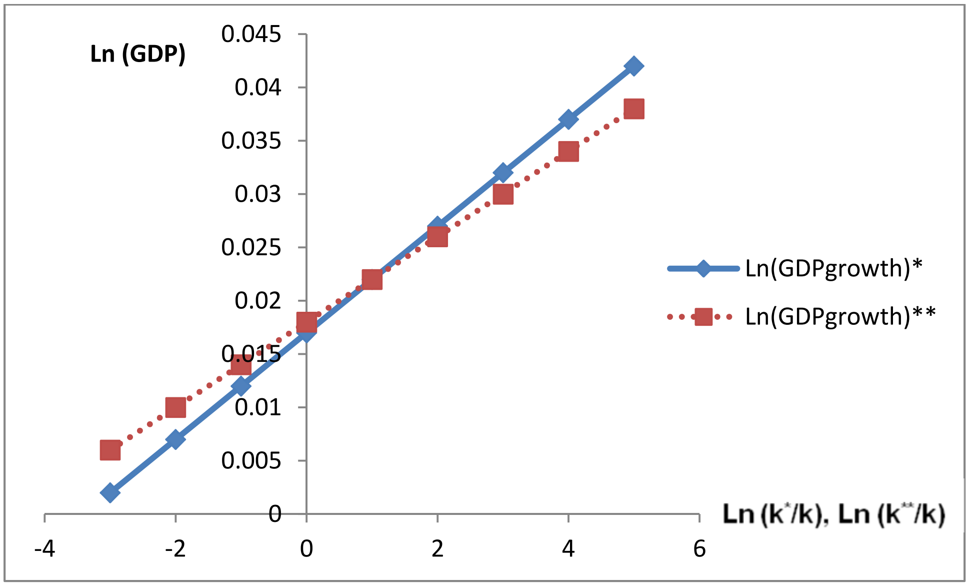
$Ln(\pi) = 0.161 - 0.025 \ln(k^*/k)$, $Ln(\pi) = 0.161 - 0.014 \ln(k^{**}/k)$



$Ln(N) = 0.007 - 0.013 \ln(k^*/k)$, $Ln(N) = 0.009 - 0.011 \ln(k^{**}/k)$

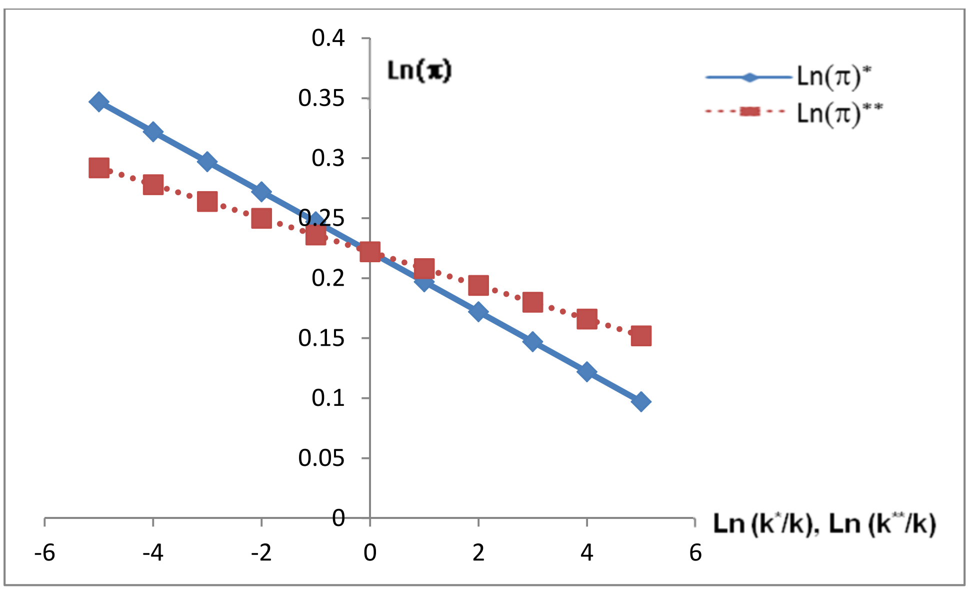


$Ln(GDP) = 0.017 + 0.005\ ln(k^{*}/k)$, $Ln(GDP) = 0.018 + 0.004\ ln(k^{**}/k)$

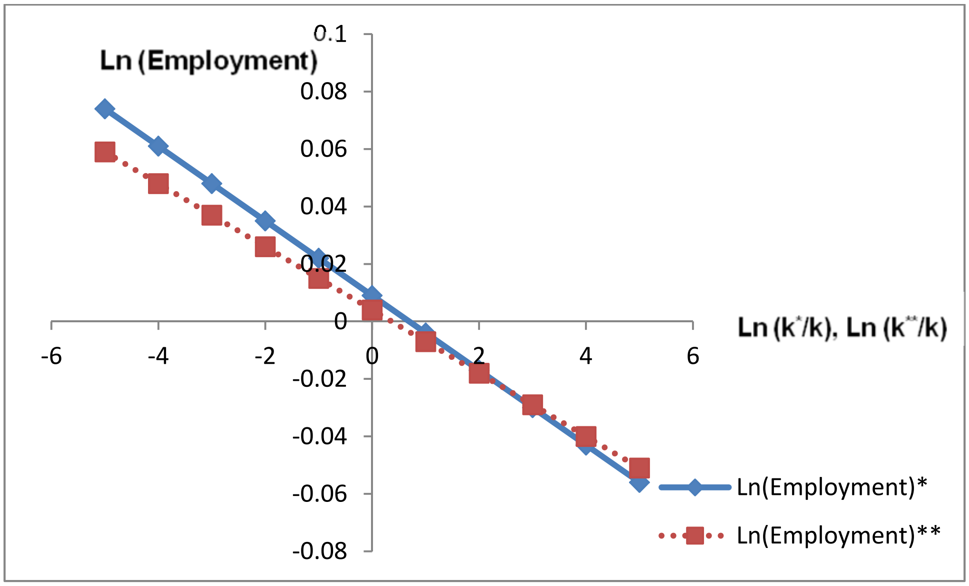


- USA

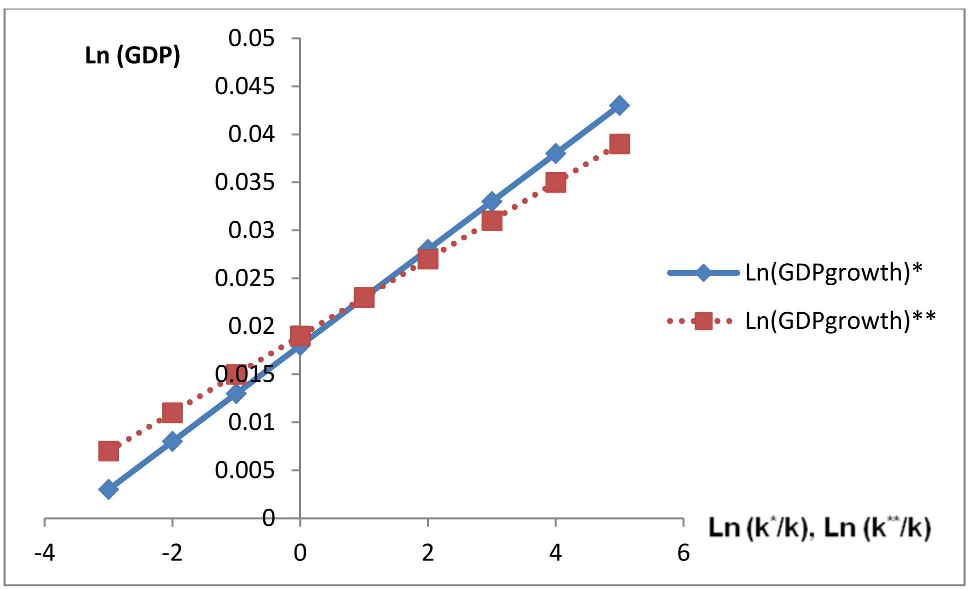
$Ln(\pi) = 0.222 - 0.025\ ln(k^{*}/k)$, $Ln(\pi) = 0.222 - 0.014\ ln(k^{**}/k)$



$$\text{Ln(N)} = 0.009 - 0.013\ \ln(k^{*}/k),\ \text{Ln(N)} = 0.004 - 0.011\ \ln(k^{**}/k)$$

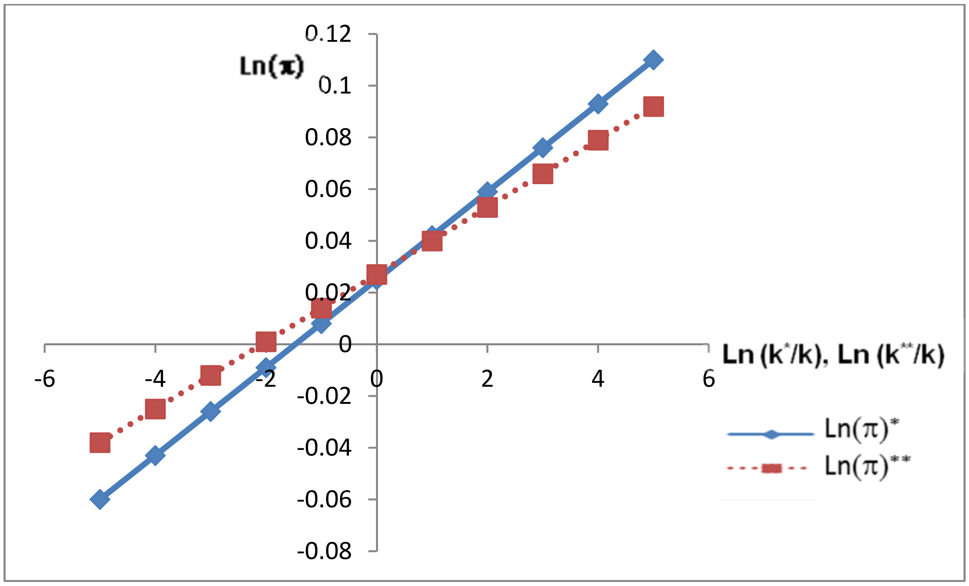


$$\text{Ln(GDP)} = 0.018 + 0.005\ \ln(k^{*}/k),\ \text{Ln(GDP)} = 0.019 + 0.004\ \ln(k^{**}/k)$$

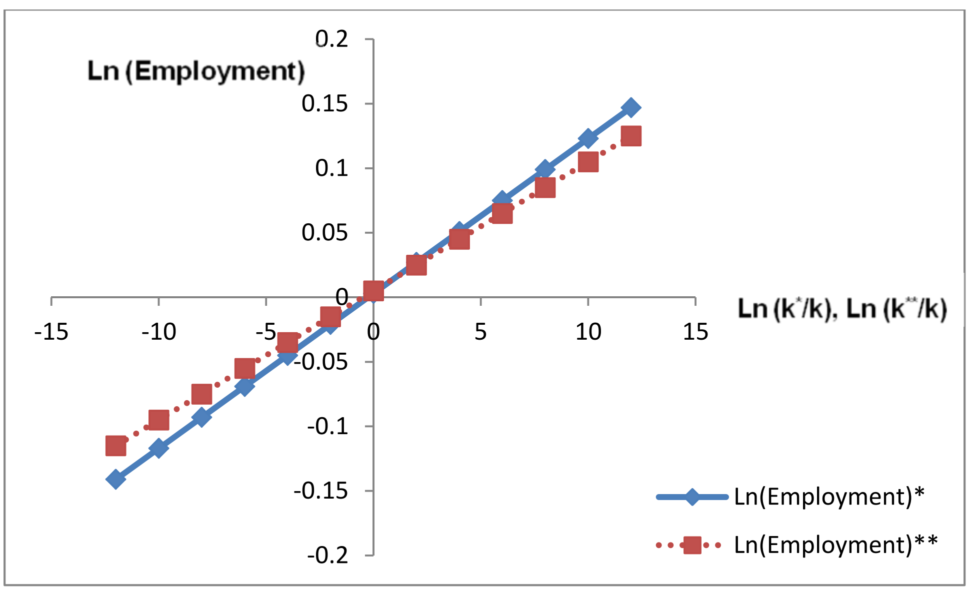


- FRA

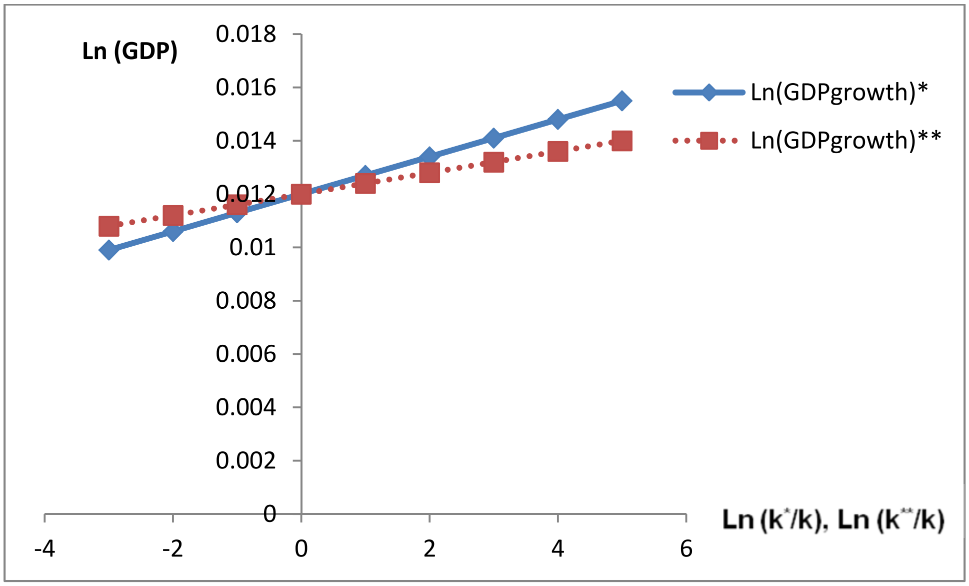
$Ln(\pi) = 0.025 + 0.017\ ln(k^*/k)$, $Ln(\pi) = 0.027 + 0.013\ ln(k^{**}/k)$



$Ln(N) = 0.003 + 0.012\ ln(k^*/k)$, $Ln(N) = 0.005 + 0.010\ ln(k^{**}/k)$

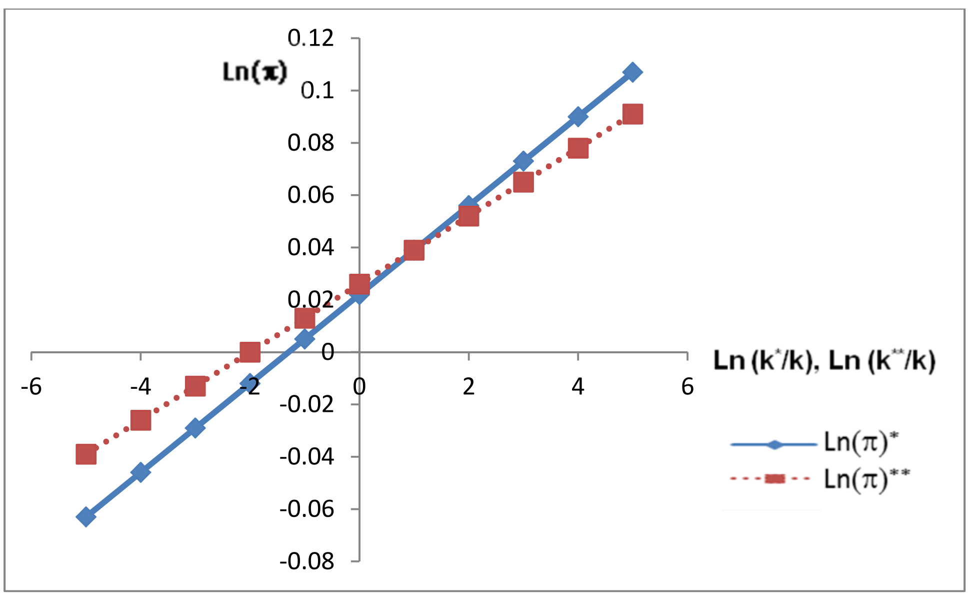


$Ln(GDP) = 0.012 + 0.0007 \ln(k^{*}/k)$, $Ln(GDP) = 0.012 + 0.0004 \ln(k^{**}/k)$

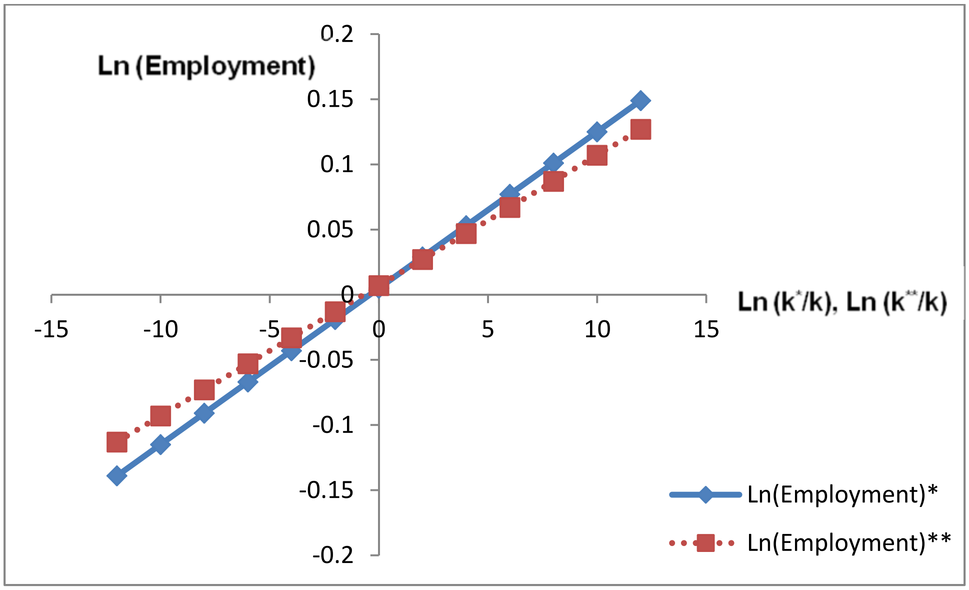


- GER

$Ln(\pi) = 0.022 + 0.017 \ln(k^{*}/k)$, $Ln(\pi) = 0.026 + 0.013 \ln(k^{**}/k)$



$Ln(N) = 0.005 + 0.012\ ln(k^*/k)$, $Ln(N) = 0.007 + 0.010\ ln(k^{**}/k)$



$Ln(GDP) = 0.013 + 0.0007\ ln(k^*/k)$, $Ln(GDP) = 0.013 + 0.0004\ ln(k^{**}/k)$